MEMORANDUM.

This electrical handbook is one of a series of ten similar handbooks prepared under the auspices of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS by the local Reception Committees in the Cities of Boston, New York, Schenectady, Montreal, Niagara Falls, Chicago, St. Louis, Pittsburg, Washington, and Philadelphia. These are the stopping places on the circular tour organized by the INSTITUTE for the reception and entertainment of its foreign guests who visit the United States in connection with the International Electrical Congress at St. Louis, September 12th to 17th, 1904. It is hoped in these handbooks to present short historical sketches of the cities visited and a rapid survey of the power plants and important electrical industries along the route.

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AS TO THE CITY OF WASHINGTON.

AMONG the cities where commerce reigns and manufactures hold sway there is keen competition. There is only one National Capital. Though a score of communities scramble for such local distinction as may be extracted from the self-applied term "metropolis," there is only one center of government of the United States. By din and roar and rattle and smoke hundreds of towns deservedly achieve rank in the realm of industry. There is only one incomparable residence city in the United States. That is the city of Washington; the city that charms men and delights women at all seasons of the year.

Washington's government is not of the so-called popular form, but it comes nearer to being popular with all the parties directly concerned than any other variety of municipal government operating in this country at this time. Three Commissioners are appointed by the President of the United States. These Commissioners—frequently termed the "triumvirate" by those who would prefer other commissioners—frame estimates for the municipal sustenance of the District of Columbia, urge Congress to permit the District of Columbia to spend the money which the District raises through taxation, and then, when appropriations are made, see that they are properly disbursed. The Commissioners are generally men of prominence—one of them is required by the law to be an officer in the Corps of Engineers of the Army—and it is superfluous to add that they are scrupulously honest. As a consequence, all moneys are expended as the law directs and without the discounting intervention of a Board of Aldermen and a Common Council. The novelty of this condition must appeal strongly to persons who have resided in cities where tax-payers' contributions are regarded as legitimate spoils for the city's fathers and their friends. The idea that the people of the District of Columbia get a dollar's worth of material for

a dollar must be extremely fascinating to the plucked American who has breathed the atmosphere of municipal carelessness, not to say corruption. So it comes to pass that, even with insufficient appropriations, Washington is the most delightful of American cities because it is the best governed; because its municipal administration is unmunicipally business-like and completely devoid of dishonesty's taint.

MISUNDERSTOOD RELATIONSHIP.

One of the important things not generally understood by the public at large is the peculiar relationship existing between the General Government and the other tax-paying residents of the District of Columbia. That relation should be of interest to every American. There is an impression abroad in the land—frequently evident in Congress—"that Washingtonians are mendicants, dependent upon the national bounty, untaxed or lightly taxed, and draining, vampire-like, the life-blood of every Congressman's tax-burdened constituents." If such an impression had any foundation in fact, Washington's growth would soon reach phenomenal proportions. The human desire to get as much as possible for nothing would give the District a population of more than a million within a decade. The truth is that Washingtonians pay their share of all bills and are not indebted in any way either to the General Government or to the component parts thereof which are located without the limits of the District of Columbia.

In June, 1783, Congress was in session in Philadelphia. Some of the Revolutionary soldiers had grievances, and they threateningly organized and marched toward the then seat of Government. Both the State and local authorities confessed themselves unable to control the invaders, so Congress fled precipitately. Thus was the necessity for a truly National Capital driven home, and as the result came the Constitutional provision which led to the cession of territory, ten miles square, by Maryland and Virginia—the District of Columbia—the site of what President Washington called the Federal City, which, in 1800, became the seat of Government.

In all the original city site there were 6,111 acres. The original owners donated to the United States for streets and alleys 3,606 acres, and 982 additional acres, divided into 10,136 building lots. The United States then purchased for its own uses 541 acres more, its total holding amounting then to 5,129 acres. All that the original owners received were 982 acres, subdivided into 10,136 lots. It was provided that the 541 acres purchased for public building sites and reservations should be paid for out of the first proceeds of the lots donated to the Government. This was done; so the Government did not pay even one cent for the vast quantity of soil it owns in the District of Columbia.

In a recent Board of Trade publication the then president of the organization sketched briefly the conditions which prevailed as to the National Capital partnership from the time of the initial agreements as to maintenance until the year 1878, when the organic law now in operation was enacted.

"The original owners of Washington," said the writer, "donated five-sevenths of the city's soil and yielded the right of self-government to the Nation on the understanding and implied agreement that the Nation was to build up here a magnificent capital, at its own expense, reimbursing itself in part from the proceeds of the sale of the donated lots. A pretentious city was planned, and lots were sold by the Government on the strength of this understanding. Patrick Henry complained that the residents of the District might, under the arrangement, 'enjoy exclusive emoluments to the great injury of the rest of the people,' and pamphlet protest was entered against Congress meeting all the needs of the capital, on the ground that the independence and self-respect of its citizens would be degraded. It was from the beginning, in theory at least, the city of the Nation, and not the city of its residents, and the primary responsibility for its development has always been in equity upon the Nation, and the residents, who have no voice in the disposition of the

money exacted from them, are the incidental contributors. In spite of this conceded relation of Nation and capital, the local tax-payers of the District for three-fourths of a century were compelled to assume practically the entire burden of capital-making, the Nation violating and neglecting the obligations which it had incurred. In 1878 the amount of the contributions of the resident tax-payers toward the expenses of the capital were fixed by law at one-half the total amount, the Nation tardily and inadequately fulfilling its original agreement."

TREES, PARKS, HOMES.

Countless shade trees and scores of miles of broad asphalted streets would of themselves make Washington worthy of a visit, but they are only two of the many items which go to make up the sum total of urban desirability. Scattered liberally throughout the length and breadth of the city are parks (officially known as Government reservations). Some of these parks are merely grass-planted triangles, contributing to the fascinating geometrical design which caused it to be said that "Washington was modeled after Versailles and Versailles from a spider's web." Others are great squares or circles where streets and avenues converge; a setting of emerald for choice plants and flowers, and frequently sites for statues of soldiers, sailors and statesmen. Still others cover extensive territory. Rock Creek Park contains more than eighteen hundred acres; the Zoological Park has nearly two hundred acres; the Mall stretches from the Capitol to the Potomac. By-and-by there will be another great park. For years man and machinery have toiled to change the once-noisome and pestilential river marshes into a pleasure ground, and the bulk of the work has been done. Inclosed within a strong sea-wall the old river-bed has been transformed into tree-growing soil until there is a vast expanse of high ground which in the near future will be placed in the keeping of landscape gardeners to the end that the public may be pleased, edified and physically bettered.

Suburban Washington is extremely beautiful. It is

beautiful even when compared with the city. It abounds in feasts of landscape, in highland sites and woodland retreats, in superb drives, crystal streams, fine travel facilities and the best of good society. From the swift-flowing and disturbed Potomac on the west, over the hills and valleys of the north and east, around to the now broader and majestic river on the south, there is a continuous chain of subdivisions within the links of which the new-comer may find enough of picturesque variety to puzzle him when he desires to make choice. Here is an attractive field for the investor. Washington's growth is no longer a matter of surmise.

Diversity of architecture is one of the reasons why Washington is such a desirable place of residence. Years ago many cities became enamored of certain styles of architecture, and it seemed almost impossible for any considerable number of people to depart from the designs which pleased their fathers and grandfathers. There has never been any such formalism in Washington. No long rows of undistinguishable houses precisely alike in every external and internal detail, and monotonous at all times, destroy Washington's claim to municipal individuality. Architectural independence is the rule and it has worked admirably. Instead of wearisome lanes of red bricks, white doorsteps and green blinds are the esthetic products of modern brains and sympathetic hands. This quality is by no means confined to the great mansions; in fact, it is more common in the less pretentious homes. Household art is a notable Washington characteristic.

VITAL FIGURES.

Some figures are confusing. Some are untruthful. Some are unattractive. The vital statistics of the National Capital are clear, accurate and gratifying. With a total population closely approximating three hundred thousand, in 1902 the white death rate was 15.92 per thousand inhabitants, the number of that class being about two hundred thousand, five hundred. The colored residents of the District of Columbia numered then something like ninety thousand and their

THE NATIONAL MONEY BANK.

death rate was 29.13. The whole death rate was 19.99. Small as the rate is—swollen, however, by the much larger mortality of the negro—it lessens steadily. Twenty-four years ago the white death rate was 19.54, while the colored mortality was represented by 40.78. Since that time medical science and education have wrought wonders; not spasmodically, but continuously and solidly. Shallow wells have been filled up, marshes drained and streets cleaned, water-supply increased, milk carefully inspected, food adulterations sought and located, surface drainage stopped and sanitation taught. Countless efforts to defend the public from itself and its hardly less active enemies have brought forth marvelous results. A vigilant and efficient Health Department has so taken advantage of the broad highways and the natural sanitary conditions as to render the inhabitants proof against any scare of an epidemic. In no other city in the country is there less chance for the spreading abroad of any plague-like affliction.

A common community weakness is boastfulness as to the local climate. Washington does not boast of its climate, but it extracts a great deal of quiet satisfaction from the fact that in the summer it is much cooler than are many cities to the north of it. Southern breezes of which so many centers of populations complain during the summer season reach Washington cooled by a thousand miles of intimacy with the Atlantic Ocean and more than two hundred of miles of close communion with the Chesapeake and the Potomac. Even when the days are really hot the sun's heat has not that deadly effectiveness which is common in more northern cities. The local record of sunstrokes and heat prostrations shows almost entire immunity from fatal cases; a record which contrasts strongly with that made in the densely inhabited and narrow streets of such cities as New York, for instance. There have been times, too, when Washington has luxuriated in warmth while regions much nearer the equator have shivered in the clasp of the ice king. There is probably no place in all the eastern

portion of the United States where the temperature is more nearly equable than in the District of Columbia. Many invalids come to Washington during the fall and remain until it is time to visit the mountains or the seashore. The fact that Washington is situated in the great peach-growing belt is proof conclusive as to the mildness of its climate.

THE BEST SCHOOL IN THE COUNTRY.

As an educational center Washington has many advantages over other American cities. One in every five hundred of its inhabitants is a scientist of more than local repute. Nowhere in all the Western Hemisphere can there be found such a vast store of educational material. Here is the only place where the study of the Government of the great republic is possible. Here is the machinery which accomplishes so much. Here, all the year round, the executive branch puts in operation the plans committed to its keeping by that body which directly represents the people. Years might profitably be spent by students in observing the methods of presidents, cabinet officers, chiefs of bureaus, clerks and even the holders of humbler positions. Here Congress meets and affords ample opportunity for the careful investigator into our legislative methods. Hither come the politicians, the seekers after office, the manipulators of the "pulls," the statesmen without visible means of support, the claimants, the men who hope to be but never are.

Object lessons, however, are not the only lessons taught in Washington. Here is the great Library of Congress, housed in a magnificent structure the decorations of which are the admiration of the art world; a library that seems to lack little of comparative completeness. Here are the government departments, each rich in material for study. Here is the Smithsonian Institution and National Museum. Here is the Corcoran Gallery of Art, a great collection splendidly sheltered. Here are universities and colleges and schools in profusion. A public library, only recently established, will soon, it is hoped, be sufficiently developed to supply the literary demands of this more

than ordinary intelligent community. The building in which this library has its home is a notable contribution to architectural Washington.

Washington has strong social tendencies, and these, combined with the refined cosmopolitan character of Washington's population, add largely to the city's attractiveness as a place of residence. Here may be found the best representatives of European, Asiatic and American civilization; some of them prominent in the official world, others conspicuous in business affairs; still others content only on enjoying the fruits of their toil and the remnant of their days.

Official Washington is notable. While Congress is in session there can not possibly be complaint of dullness. There are banquets at the Executive Mansion; Presidential receptions to the Supreme Court, the Diplomatic Corps, the Houses of Congress, the Army and Navy, and the general public; weekly receptions by members of the Cabinet; Diplomatic Corps "at homes;" dinners galore; all the varieties of teas; theater parties without number; and a judicious sprinkling of opportunities to be at once fashionable and charitable. It should be understood, however, that Washington society is not wholly official nor is it altogether open to the possessor of any place in the Blue Book. Non-official Washington has a social circle in which may be found many delightful people whose qualities are solid and enduring; the best elements of all social life and worthy representatives of the men and women who have made the city what it is—a Capital of which the Nation is justly proud.

Washington is well equipped with places of rational amusement. There are first-class theaters and second-class theaters and even third-class theaters. In the summer time there are continuous trolley excursions to glens and groves and lakes; river excursions many times a day; railroad trips to fresh, brackish or salt water; and gardens devoted mainly to the sale of liquors which in certain seasons of the year are supposed to have cooling properties.

Cabin John Bridge.

Light manufacturing could not find a more congenial home than in or in the immediate vicinity of the District of Columbia. At this time the enormous water-power of the Potomac is unused, but the day of such extravagant and inexcusable wastefulness is rapidly passing. A company is now planning to convert into electrical force the rushing torrents of the river at Great Falls and to convey that same force into the city for illuminating and propulsive purposes. That breach will probably result in the downfall of the wall which has until now shut out the industrious who have long grieved at their inability to turn to money-making use the hundreds of sites available for the less objectionable varieties of manufactures. There is a big local market for almost any kind of a factory product. Coal is brought directly by canal from the mines in the Cumberland district, and there is ample rail and river transportation.

Steam communication with the north, south, east and west is maintained by the Pennsylvania Railroad, the Baltimore & Ohio Railroad, the Chesapeake & Ohio Railroad, the Southern Railroad, the Atlantic Coast Line and the Seaboard Air Line. Electric railroads operate as far south as Alexandria, Va.; north to Rockville, Md.; east to Laurel, Md., and west to Cabin John Bridge, Md. All the prominent suburbs are electrically connected with the city. Steamboat service is constant. Three of the finest of river boats are run between Washington and Fortress Monroe, Norfolk and Newport News. Other good boats run to Mount Vernon, Marshall Hall, River View, Glymont, Chapel Point, Colonial Beach, Piney Point, all the other Potomac landings in Maryland and Virginia, and up the Chesapeake to Baltimore.

THE REPUBLIC IN MINIATURE.

Washington's future is assured. The day of doubtings, of fears, and of little things, has departed forever. President Noyes, of the Washington Board of Trade, put that very happily when he said "The ward of the nation will never again be starved and ill-treated by its guardian, once contemptuous, now grown

proud and affectionate. In the present partnership of nation and nation's city the former has endorsed the latter's promise to prosper as well as to pay. The swelling prospects of other places that attract men may collapse, mineral deposits may fail, tariff changes may ruin the business of a manufacturing town, fickle commerce may flow in other channels, but the fortune of the republic and its capital are inseparably interwoven, and, while the States of the Union endure and flourish Washington as the nation's city will show forth the republic in miniature, responding in its own growth to the national development and prosperity."

ELECTRICAL DEVELOPMENT IN THE UNITED STATES.

IT would not be unfair or unsafe to take the electrical development of a people, or the extent to which a nation uses electrical applications, as a gauge of its civilization; and from this point of view the data herewith given as to the extent of the industries that are based on electricity in the United States may have more than a passing value. So far as is known, this country is the only one in which a sustained effort has been made by the Government to submit to the statistical processes of census inquiry the whole range of the electrical arts; but it is believed that in a few years similar figures will be obtainable for all portions of the civilized world, enabling any country to measure itself with others as to its utilization of the telegraph, the telephone, the trolley, the electric light, the electric motor and other kindred appliances by means of which intelligence can be swiftly transmitted, distances be shortened, the darkness brightened, labor lessened, and sickness alleviated. While some figures have been available as to certain branches of electrical work, in various countries, at different times, the rapid growth of this essentially modern department of discovery and endeavor renders it highly necessary that every civilized country should now furnish for itself and others all these important bases of comparison.

As to the United States of America, it seems only natural that with its time-consuming remoteness from the Old World, its vast natural resources, its energetic population, and its bent for industrial organization,

associated with an unusual keenness of the inventive faculties, there should have been manifested a swift appreciation of all the benefits that practical electricity could bestow. Hence, as a matter of fact, the average annual expenditure per head of the population in the United States of America is virtually not less for electrical current and supplies than for daily bread. Such a statement, which may at first glance appear astounding, is easily tested. The outlay annually on actual apparatus is equal to $2 per head. The toll paid to the trolley systems of the country is $3 or better per head. The earnings of the electric light companies are just about $1 per head, while the value of the service given by isolated plants is reckoned as approaching the same amount. The earnings of the telegraph companies reach roughly 50 cents per head, and the telephone companies get slightly better than $1 per head. To these items must be added those due to the outlay on a long list of other services, including electricity in mines, in medicine, in elevators, in automobiles, etc., and it will be seen that a total, fully authenticated in all respects, is reached of at least $8.50 to $9 per head per year. Surely such an expenditure is not surpassed or even equaled in any other country in the world. It is equally certain, as thus demonstrated, that the American of today lives as much by electricity as by bread.

The industrial branches of American electrical development may now be taken up in brief review, using the data chiefly that has been systematically collated since the last general census of 1900-1 by the United States Bureau of the Census in Washington, when for the first time an investigation was made separately as to the production of electrical apparatus and supplies—an inquiry that will be repeated in the manufacturing census of 1905, as required by Congress. The average growth in such production is found to have been at the rate of 15 to 20 per cent. for the last twenty years. Hence the esti-

mated output during 1903 was as follows, based upon the official returns of 1900-1:

Dynamos	$17,000,000
Transformers	5,000,000
Switchboards, for lighting and power	2,750,000
Motors, for all purposes	30,000,000
Storage batteries	4,500,000
Primary batteries	1,250,000
Carbons	2,000,000
Arc lamps	2,250,000
Incandescent lamps	5,500,000
Lighting fixtures	3,750,000
Telephonic apparatus	25,000,000
Telegraphic apparatus	2,000,000
Insulated wires and cables, submarine cables	30,250,000
Conduits, interior and underground	1,750,000
Rheostats, heating and cooking apparatus	2,500,000
Annunciators	250,000
Electric clocks	150,000
Lightning arresters, fuses, etc	750,000
Measuring instruments	3,000,000
Miscellaneous apparatus	19,000,000
	$158,650,000

All these figures are, as noted above, predicated on the actual reports filed in the census of 1900-1, showing nearly $105,000,000 in that year, and check closely with the annual reports published by the leading manufacturers. The capital and labor employed cannot be given with corresponding approximation, on account of consolidations, new industries, greater use of automatic machinery, etc., but it may be noted that in 1900-1 strictly electrical manufacturers filed their returns with the census office to the number of 580. These concerns and individuals employed 45,877 persons and had $83,-130,943 capital engaged in the business. The ratio of increase in these three items has not been quite so high as in output. An industry that has attained a production of $150,000,000 in manufactured goods must obviously stand high among the leading occupations in

the country. It must, moreover, be recollected that all of this apparatus serves as an underlying constituent of great public service systems and plants for railway work, lighting, telephony, telegraphy, etc.; so that in the whole industry the actual increase in investment, inclusive of real estate, buildings, line construction track, engines, waterwheels, etc., would represent not far short of $750,000,000. The annual increase in capitalization in the street railway field alone is now about $450,000,000; although, of course, capitalization is not to be taken as synonymous with investment.

The Telegraph is the oldest public service industry in the United States of America, as it is elsewhere, but, as the figures show, it is also the smallest. Indeed, each new industry has apparently rolled forward with a bigger wave, the telegraph, telephone, electric light and electric railway each being larger than its predecessor in strict order and succession. Whether this relation of magnitude will be maintained, cannot be foretold, but it has persisted for some years, and encourages thoughtful speculation as to the place that electric power is now taking universally for the propulsion and operation of mills, factories, mines, docks, printing plants and a thousand other kinds of industrial establishment. It is all, however, evolutionary from the telegraph.

The Director of the Census has issued a preliminary report on the commercial telegraph systems of the United States for the year ending December 31, 1902. The report includes only commercial telegraph companies owned and operated within the United States, which were in operation during any portion of the year, no statistics being given for foreign telegraph companies operating in the United States.

Number of companies	21
Common stock: (1)	
Authorized, par value	$104,383,075
Issued, par value	99,870,225
Gross income	37,552,450
Total expense	28,490,219
Dividends and interest on bonds	6,084,919
Net surplus	2,977,312

Miles of wire operated..................	1,248,602
Number of messages sent during 1902.....	90,844,789
Number of telegraph offices...............	27,352
Batteries in offices:	
Primary—Number of cells..............	634,491
Storage—Number of cells..............	19,639

(1) Exclusive of the capitalization of the Postal-Telegraph Cable Company, which was reported as $100,000.

It is to be observed in passing that herein are included no figures of railway telegraph—the steam railroads of the country all having elaborate message and signal services, but presenting no general statistics. One important branch of telegraphy that must not be overlooked, however, is that of the municipal electric fire alarm and police patrol systems. In regard to these, the Census Office has issued this year an interesting report, the first of its kind. From this it appears that in 1902 there were 764 fire alarm systems, with 2,798 miles of pole line owned and 10,952 miles leased; with a total wire of 28,302 miles, out of which 28.8 per cent. was underground in 859 miles of conduit. Distributed along these circuits were 37,739 signalling boxes or stations, of which 34,776 were on poles or posts and 2,963 in booths, etc.; or one to the mile of circuit, roughly. In 1902 these boxes reported 85,070 fire alarms, or between two and three to the mile of circuit. The central office apparatus comprised 155 manual transmitters, 295 automatic transmitters, and 452 receiving registers of all kinds, grouped at the various central offices or fire headquarters. These were associated with 1,973 receiving and 1,361 transmitting circuits, connected with 214 telegraph switchboards, and with 62 telephone switchboards with a total capacity of 6,480 drops or lines. The "single circuits" extending from headquarters and returning thereto were 442. Current was furnished by 57,010 cells of primary battery and 49,327 storage cells. No very definite data can be given as to employees and salaries, as the duties are so frequently combined with those of other or non-electrical work,

CONSTRUCTION, EQUIPMENT, ETC.

Number of systems	4,151	3,157	994
Miles of single wire	4,350,486	4,779,571	70,915
Telephones of all kinds	2,315,297	2,225,981	89,316
Number of subscribers	2,137,256	2,048,736	88,520
Number of automatic pay stations	73,887	73,869	18
Number of all other pay stations	48,393	48,009	374
Farmer or rural lines owned by com. systems:			
Number of lines	15,598	15,598	....
Miles of single wire	138,426	138,426	....
Number of telephones	121,905	121,905	....
Number of party lines	258,166	(1) 248,908	(2) 9,258
Number of telephones on party lines	886,152	308,571	77,581
Number of public exchanges	10,361	9,419	942
Number of private branch exchanges	7,883	7,883	....
Manual switchboards, total number	10,842	9,901	941
Common battery system	837	830	7
Magneto system	10,005	9,071	934
Automatic switchboards	54	53	1
Mes or talks during year, total No	5,070,555,345	4,971,413,070	99,142,275
Local exchange	4,949,850,491	4,851,416,539	98,433,952
Long distance and toll	120,704,854	119,996,531	708,323
Employees and Wages:			
Salaried officials and clerks:			
Total number	14,124	13,958	166
Total salaries	$9,885,886	$9,871,596	$14,290
Wage-earners:			
Total average number	64,628	63,630	998
Total wages	$26,369,735	$26,206,065	$163,670
Revenue and Expenses:			
Total revenue	$86,825,536	$86,522,211	(3)$303,325
Total expenses (including taxes and fixed charges except int. on bonds)	61,152,823	60,871,002	281,821
Dividends paid	14,982,719	14,981,649	1,070
Interest on bonds	3,511,948	3,511,768	180
Net surplus	7,178,046	7,157,792	20,254

(1) Urban party lines.

(2) Rural party lines.

(3) Includes assessments.

CONDENSED BALANCE SHEET.

	Total.	Commercial.	Mutual.
Total assets	$452,172,546	$449,485,693	$2,686,853
Construction and equipment (including real estate and telephones)	389,278,232	386,662,619	2,615,613
Stocks and bonds of other companies	9,938,342	9,938,342	....
Machinery, tools and supplies	9,689,691	9,657,956	31,735
Bills and accounts receivable	30,629,677	30,619,294	19,383
Cash and deposits	12,291,840	12,271,718	20,122
Sundries	344,764	344,764	....
Total liabilities	452,172,546	449,485,693	2,686,853
Capital stock	274,049,697	273,388,432	661,265
Bonds	73,981,361	73,978,361	3,000
Cash invested (unincor. systems)	6,161,299	4,571,318	1,589,911
Bills and accounts payable	44,491,066	44,411,639	79,427
Sundries	1,124,265	884,561	289,704
Net surplus and reserves	52,364,858	52,301,382	63,476

In addition to the reports obtained from commercial and mutual telephone systems, shown in the above table, the bureau secured reports of 4,985 "independent" farmer or rural lines having 49,965 miles of single wire and 55,747 telephones. These figures added to the totals for the commercial and mutual systems give a grand total for the continental United States of 9,136 systems and lines, 4,900,451 miles of single wire and 2,371,044 telephones.

A number of commercial systems operate in rural districts, but combining the totals for farmer or rural lines owned by commercial systems, mutual systems and independent farmer or rural lines gives a total of 21,577 systems and lines, 259,306 miles of single wire and 266,-968 telephones, operated exclusively in rural districts.

In addition to the statistics presented above for the continental United States, reports were received for one commercial system in Alaska and seven in Hawaii, having a total of 4,732 miles of single wire, 2,493 telephones of all kinds, 3,461,000 messages or talks during the

year, \$112,068 total revenue, \$76,307 total expenses (including taxes and fixed charges), and \$25,858 paid in dividends, leaving a net surplus of \$9,903.

Until a few years ago the whole telephonic development of the United States was done under the aegis of the "Bell system." With the expiration of fundamental Bell patents, a movement developed, striking and widespread, known as the "independent," as the result of which competition has been developed on a large scale peculiarly illustrative of the energy and rapidity with which enterprises are often pushed in America. An equality in development with the Bell system has been claimed, indeed, and it is necessary to note the fact, as many telephonic comparisons between the United States of America and other countries based on Bell statistics alone are obviously erroneous and far from doing justice to the facts. It may be doubted whether the "independent" statistics, extraordinary as they are for the very short period of time over which they extend, equal those of the Bell system, twenty-five years old; but they must be taken into account. It would appear from the figures above that the capitalization per telephone installation is about \$195. It is generally conceded from the fact that the Bell system is largely centered in the cities, that the capitalization for the Bell installations would necessarily be heavier than for those in the independent networks. On the basis of \$195 over the entire industry, and accepting the Bell stations at the end of 1902 as being only 1,277,983, it would appear that the Bell investment was much the larger half. The total revenue is placed at nearly \$87,000,000, but at only \$50 per station the Bell figures would represent at the end of 1902 \$64,000,000, or nearly 75 per cent. The total of single wire for the whole industry is placed at 4,850,486 miles. The Bell system at the end of 1902 had slightly more than half this. The total number of telephone talks is given as slightly over 5,000,000,000 for the whole industry, while the figures for the Bell system for 1902 were given in the annual report of that year as 3,000,000,000. The increase in the investment in telephony is supposed to reach from fifty to seventy-five millions a

year at the present time, but on this basis the Bell system holds its own, for the total amount added to construction and real estate by the companies in the system during 1903 was put down at $35,000,000, while in 1902, the year of the census report, it is even said to have reached $37,000,000.

The visitor to the United States from abroad must therefore bear these figures in mind in comparing American with other telephonic development, and especially in using the data given in the Bell telephone literature compiled for and distributed at the St. Louis Exposition. According to these admirable little pamphlets, the Bell system in 1881 connected 463 cities, towns and villages. In 1904 it connected 26,128. In 1881 it had 47,880 subscribers; in 1904 it had 1,525,167. In 1881 the ratio of telephone subscribers to total population was 1 to 1,074, where in 1904 it is 1 to 53. In 1881 the average daily number of telephone communications was 300,000. In 1904 it reaches 10,134,020, a gain from 2 per inhabitant to 42. The number of employees rose from 1,650 in 1881 to 61,135 in 1904. These and other data must all be revised by the census figures in order to arrive at a more comprehensive idea of telephonic development and utilization in America.

The latest American figures obtainable for the electric light and power industry are those of the Census Office for the year ending June 30, 1902, since when central station work has undergone a very considerable development. It is to be borne in mind that these figures do not include any data for isolated plants, estimated roughly at 50,000, with a consumption of material and an output of current fairly commensurate with those of central stations. It must also be pointed out that in addition to what the central stations do, no fewer than 252 electric railway companies in 1902 reported the generation of current for sale for light and power purposes, and that 118 of those had accounts itemized sufficiently to show gross earnings from it of $7,703,574. The figures for 3,619 authentic central station figures follow, adding that the capital stock and funded debt issued was:

	Total.	Private.	Municipal.
Number of establishments	3,619	2,804	815
Cost of plants	$502,181,511	$480,161,038	$22,020,473
Earnings from operation, total	83,585,410	76,748,554	6,836,856
From light service	69,731,931	62,983,068	6,748,863
Arc lighting	25,459,437	22,070,192	3,389,245
Commercial or private	8,443,280	8,203,114	240,166
Public	17,016,157	13,867,078	*3,149,079
Incandescent lighting	44,272,494	40,912,876	3,359,618
Commercial or private	41,536,392	38,668,096	2,868,296
Public	2,736,102	2,244,780	*491,322
All other electrical service	13,853,479	13,765,486	87,993
Income from all other service	1,560,013	1,431,761	128,249
Gross income	85,145,423	78,180,318	6,965,105
Expenses:			
Total	67,688,075	62,442,088	5,245,987
Salaries and wages	20,551,989	18,672,267	1,879,722
Supplies and materials	22,814,758	20,392,467	2,422,291
Rent of stations and offices	1,285,546	1,270,798	14,748
Taxes	2,654,065	2,643,945	10 120
Insurance	886,445	820,804	65,641
Miscellaneous	6,994,227	6,645,567	348,660
Interest on bonds	12,501,045	11,996,240	504,805

* Estimated value if paid for at prevailing rates.

The average number of employees, with total salaries and wages, was as follows:

	Total.	Private.	Municipal.
Average number of employees and total salaries and wages:			
Salaried officials and clerks	6,976	6,026	950
Salaries	$5,632,880	$5,174,499	$457,381
Wage-earners	23,258	20,791	2,467
Wages	14,919,109	13,496,768	1,422,341
Foremen and inspectors	1,560	1,478	82
Wages	1,358,272	1,297,585	60,687
Engineers and firemen	8,020	6,671	1,349
Wages	5,201,988	4,416,929	785,059
Linemen	4,209	3,860	349
Wages	2,704,529	2,503,957	200,572
All other employees	9,469	8,782	687
Wages	5,654,320	5,278,297	376,023

The power plant equipment was:

	Total.	Private.	Municipal.
Power-plant equipment:			
Steam Engines—			
Number	5,921	4,861	1,060
Horsepower	1,377,041	1,230,023	147,018
Water wheels—			
Number	1,378	1,296	82
Horsepower	381,134	396,916	11,218

Generating plant:	Total.	Private.	Municipal.
Dynamos—			
Direct-current, constant voltage—			
Number	3,820	3,402	418
Horsepower	441,621	418,088	23,533
Direct-current, constant amperage—			
Number	3,537	2,955	582
Horsepower	195,431	157,668	37,763
Alternating and polyphase current—			
Number	5,106	4,284	822
Horsepower	978,428	887,740	90,688

The output of the generating equipment and the nature of the apparatus consuming current were as follows:

Output of station:	Total.	Private.	Municipal.
Kilowatt hours—total for year	2,507,051,115	2,311,146,676	195,904,439
Line construction:			
Miles mains and feeders	12,470,494	10,936,603	1,533,891
Lighting service:			
Arc lamps—			
Total number	385,208	334,413	50,795
Commercial or private	173,502	167,709	5,793
Public	211,706	166,704	45,002
Incandescent lamps –			
Total number	18,006,521	16,429,060	1,577,461
Commercial or private	17,552,756	16,058,111	1,494,645
Public	453,765	370,949	82,816

These figures are subject to the correction or enlargement of the 118 street railway companies noted above. These companies showed an aggregate of $6,469,726 from such service, of which $4,074,684 was from commercial lighting and $1,417,985 from public lighting, while no less a sum than $768,040 was earned from motor service. This income was derived from the operation of 33,863 arc lamps, of which 2,582 were open and 13,603 enclosed, in commercial use; and 10,868 open and 6,860 enclosed, in public use. In the way of incandescent lighting there were 1,442,685 lamps in service, of which the vast majority, or 1,313,303 were of 16 candle-power; while all but 19,026 of the larger number were in commercial as distinguished from public use. As to motor service, the street railway companies report supplying current to 10,049 stationary motors of 35,688 horse-power capacity. There were also 56,601 meters on the circuits. As has been noted, these are the figures given by 118 companies keeping separate accounts that enabled the compilation of these detailed statistics. There were, however, 252 companies which generated current for sale for light and power purposes.

In addition to the equipment shown above, there were employed in the central stations 193 boosters, with a capacity of 17,911 horse-power, and 132 rotaries, with a

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capacity of 63,817 horse-power. As to sub-station apparatus, the number and horse-power of storage battery cells, transformers, rotary converters and miscellaneous equipment in sub-stations were required to be reported separately. The totals are summarized in the following table:

	Total.		Private Stations.		Municipal Stations	
Kind of equipment.	Number.	Horse-Power.	Number.	Horse-Power.	Number.	Horse-Power.
Storage battery cells.....	8,388	25,284	8,388	25,284	...	....
Transformers.................	2,525	420,667	2,490	419,368	35	1,299
Rotary converters..........	163	85,556	162	85,546	1	10
Miscellaneous................	140	21,443	135	21,269	5	174

In addition to the 8,388 storage battery cells in sub-stations, with a capacity of 25,284 horse-power, there were 6,881 cells, with a capacity of 16,355 horse-power, reported for the main power plants, making the number of cells for all classes of storage batteries 15,269, with a capacity of 41,639 horse-power. It will, of course, be understood that the capacity of the storage batteries cannot be taken in definite horse-power, that depending so much on the rate of discharge; but the figures here given were such as are justified by the reports from the central stations as to battery output of current, although it was not found feasible to reduce this to horse-power-hours, the rate of discharge varying somewhat indefinitely.

In addition to the 2,525 transformers in sub-stations, with an indicated capacity of 420,667 horse-power, there are 207,151 on consumers' circuits, with a total capacity of 922,774 horse-power, making an aggregate of 209,676 transformers, with a capacity of 1,343,441 horse-power. The miscellaneous equipment consists largely of motor-generator sets and boosters.

As to the output noted, it is natural that some difficulty would be experienced in eliciting it, especially with plants carrying chiefly an arc light load, or unchecked by consumption meters. There were reported, however, 582,689 consumers' meters, of which 98.7 per cent. were electro-mechanical, the others being chemical. Each station was required to report its kilowatt-hour average per day and the total for the year, and also the horse-power of the current average per day and the total for the year. In the majority of the stations no record is kept of the output of current, and the amounts reported are largely estimates based on the voltage and amperage of the machines with reference to the hours of operation. The average kilowatt-hour out-

put of current per day for all stations is 6,814,074, and the total for the year 2,453,502,652. The horse-power-hours of current, average per day, is 9,097,796, and the total for the year 3,270,162,309. The stations operated under private ownership reported 92 per cent., and those under municipal control only 8 per cent. of the total kilowatt and horse-power-hours of current. The total dynamo capacity of central stations was 1,624,980 horse-power, or, roughly, about 1,200,000 kilowatts. As the average kilowatt-hour output of current per day is shown to have been 6,814,074, it appears from this that the electric light stations are on a basis of average daily operation for six hours, or, approximately, 25 per cent. of their possible capacity of production of current. As the gross earnings from operation are shown to have been slightly over $84,000,000, and the total production of current for the year to be 2,453,502,652 kilowatt-hours, it appears that the earnings per kilowatt-hour were not quite 4 cents. On the other hand, it is not to be understood that the central stations are able to sell all the current that they produce, as the inevitable losses between the switchboard and the consumers' lamps and motors reduce the apparent earning capacity.

The following statement shows the number of arc and incandescent lamps reported by private and municipal stations as used for commercial or other private and public service, and also the total annual income from each variety of lamp, with the average income per lamp:

Items.	Arc Lamps. Commercial or other private service.	Arc Lamps. Public service.	Incandescent Lamps. Commercial or other private service.	Incandescent Lamps. Public service.
Private stations:				
Number of lamps	168,180	166,723	16,243,853	372,740
Total income	$8,220,154	$13,871,646	$39,039,557	$2,257,927
Average income per lamp	$48.88	$83.20	$2.40	$6.06
Municipal stations:				
Number of lamps	5,793	45,002	1,494,531	82,920
Total income	$240,166	$3,149,079	$2,868,296	*$491,322
Average income per lamp	$41.46	$69.98	$1 92	$5 93

* Estimated value if paid for at prevailing rates.

There were 99,102 stationary power motors of all kinds connected with a capacity of 619,283 horse-power, reported as being in operation by private stations, and 1,962 with a capacity of 5,403 horse-power, in operation by municipal stations, making an aggregate of 101,064 stationary motors, with a capacity of 624,686 horse-power. No inclusion was made, however, of fan motors, nor of the 2,370 railway motor cars served.

As to the circuits employed in the industry, the following figures were reported:

Items.	Total.	Private stations.	Municipal stations.	Per cent. In private stations.	Per cent. In municipal stations.
Total:					
Mains	107,263.63	93.352.95	13,910.68	87.0	13.0
Feeders	17 880.51	16,452.28	1,428.23	92.0	8.0
Underground—					
Mains	5,847.71	5,408.55	439.16	92 5	7.5
Feeders	2,276.55	2,262.02	14 53	99 4	0.6
Overhead*—					
Mains	101,383.76	87,913 13	13,470 63	86 7	13.3
Feeders	15,592.59	14,181.75	1,410.84	91.0	9 0
Submarine—					
Mains	32 16	31.27	0 89	97.2	2.8
Feeders	11.37	8 51	2.86	74.8	25.2

*** Includes 79 50 miles of mains and 120.26 miles of feeders for electric railway service owned by lighting company.**

As to the circuits employed, there were 125,144.14 miles of main and feeder wires reported for both private and municipal stations. Of this total, 109,805.23 miles, or 87.7 per cent., were reported by private stations, and 15,338.91 miles, or 12.3 per cent., by municipal stations. The mains and feeders for underground circuits measured 8,124.26 miles, or 6.5 per cent. of the total, and the overhead circuits 116,976.35 miles, or 93.5 per cent. Comparatively few stations have a record of the actual length of the wires strung and ready for service, but the amounts reported were careful estimates prepared by, or under the direction of, the management of each station. In several instances it was found that electric light stations supplied current to electric railway companies, and that, in the majority of such cases, the railway companies owned the main and feeder wires over which this cur-

rent was supplied. There were, however, 199.75 miles of mains and feeders for electric railway service owned by the central stations. These quantities were included in the statistics presented.

The next and largest branch of electric industry to be reviewed is that of street railways. The general data of the Census Office report for 1902 are given in the tables below for some 987 companies, of which 817 were "operating" and 170 lessor. The first table shows the nature of the systems as compared with 1890, when the first and only previous street railway census was taken:

CHARACTER OF POWER.	1902.		1890.		Per cent. of increase.	
	Number of companies.	Miles of single track.	Number of companies.	Miles of single track.	Number of companies.	Miles of single track
United States...	849	*22,589.47	761	8,123 02	11.6	178.1
Electric..................	747	†21,920.07	126	1,261.97	492.9	1.637.0
Animal..................	67	259.10	506	5,661.44	‡86.8	‡95 4
Cable..................	26	240 69	55	488.31	‡52 7	‡50.7
Steam..................	9	169.61	74	711.30	‡87.8	‡76.2

* Includes 12 48 miles of track duplicated in reports of different companies.
† Includes 6 06 miles operated by compressed air.
‡ Decrease.

The following table reveals the vast growth in capitalization:

ITEMS.	1902.	1890.	Per cent of increase.
Number of companies........	987	706	39.8
Cost of construction and equipment....................	$2,167,634,077	$389,357,289	456 7
Capital stock issued............	$1,315,572,960	$289,058,133	355.1
Funded debt outstanding....	$992,709,139	$189,177,824	424.7
Earnings from operation....	$247,553,999	$90,617,211	173.2
Operating expenditures......	$142,312,597	$62,011,185	129 5
Percentage operating expenses of earnings............	57.5	68.4	....
Number of passenger cars...	60,290	32,505	85.5
Number of fare passengers carried..........................	4,809,554,438	2,023,010,202	137 7
Number of employees *.......	133,641	70,764	88.9

* Exclusive of salaried officials and clerks.

The following was the income account for 1902:

Gross earnings from operation			$247,553,999
Operating expenses			142,312,597
Net earnings from operation			105,241,402
Income from other sources			2,950,628
Gross income less operating expenses			108,192,030
Deductions from income:			
Taxes—			
On real and personal property	$5,835,542		
On capital stock	2,931,252		
On earnings	2,719,287		
Miscellaneous	1,592,818		
		$13,078,899	
Interest—			
On funded debt	35,223,284		
On real estate mortgages	93,078		
On floating debt	2,769,549		
		38,085,911	
Rent of leased lines and terminals		25,518,225	
Other deductions from income		912,018	
			77,595,053
Net income			30,506,977
Deductions from net income:			
Dividends on $45,047,155 preferred stock		2,053,202	
Dividends on $305,897,861 common stock		13,828,908	
			15,882,110
Surplus for year			$14,714,867

The item of $2,950,628, "income from other sources," consists principally of the interests on deposits, loans, bonds, and other securities; but it includes also income from other operations carried on in connection with street railways, such as waterworks, ice plants, etc.

The total amount, $247,553,999, given as the operating earnings of all operating companies, was composed of $233,821,548 received from passengers, $303,608 from chartered cars, $1,038,097 from freight, $432,080 from mail, $401,672 from express, $7,703,574 from sale of electric current for light and power, and $3,853,420 from miscellaneous sources.

The operating expenses, $142,312,597, are analyzed below:

Items.	Amount.	Per cent. of total.
Total	$142,312,597	100 0
Maintenance of ways and structures	12,118,296	8.5
Maintenance of equipment	16,676,532	11.7
Operation of power plant	23,062,328	16.2
Operation of cars	62,454,679	43 9
Miscellaneous	25,812,009	18.2
Wages, supplies, etc., incidental to electric service	2,188,753	1.5

The details furnished of the industry are of the most interesting and varied nature. It is to be remembered that at the time of the report the Manhattan Elevated system in New York had not been completely electrified and that a number of interurban systems now in operation were unfurnished. There were 766 companies reporting the use of electricity or other mechanical motive power. The motive power, however, was not all generated in the 805 power-houses shown, as some companies rented motive power from light and power companies.

Steam was used by 540 companies as the primary motive power to generate electric current. The statistics concerning steam power classify the engines according to horse-power. There were, in all, 2,336 engines, with a total horse-power of 1,298,133, or 556 horse-power per engine. Of this number 1,588 engines were reported as having 500 horse-power or under each, and a total horse-power of 420,551, or an average of 265 for each engine. There were 431 engines having a horse-power of over 500 but under 1,000 each, the total horse-power being 297,757, or 691 per engine, and 317 engines having a total horse-power of more than 1,000 each, the total being 579,825 horse-power, or 1,829 per engine.

There were 159 water wheels employed, with horse-power of 49,153, used as the primary power in the generation of electric current. The average horse-power per water wheel was 329. There were 129 wheels of 500 horse-power or less, 12 of over 500 and under 1,000, and 18 of 1,000 and under 2,000. Of the total horse-power, 34,215, or 69.61 per cent., was reported by 16 companies in the States of California, Georgia, Maine, Minnesota and New York. The report also shows 15 gas engines of 1,925 horse-power used for miscellaneous purposes; 301 auxiliary steam engines were reported, with horse-power of 10,074, used by 84 companies for miscellaneous purposes, driving pumps, etc. There were 3,853 steam boilers reported, with an indicated horse-power of 903,-205. The number of steam boilers exceeds the number of main and auxiliary steam engines by 1,216, while the horse-power of the engines exceeds that of the boilers

by 405,002. The average capacity of the boilers is 234 horse-power. Direct-current and alternating-current dynamos were segregated according to the horse-power, and below are given the totals for the United States:

Generators.	Direct Current. Number	Direct Current. H. P.	Alternating Current. Number	Alternating Current. H. P.
Total	2,861	972,314	441	231,924
500 H. P. or under	2,324	422,924	329	61,935
Over 500 H. P. but under 1,000	328	218,934	54	36,418
1,000 H. P. and over	209	330,456	58	133,571

The use of direct-current machines, each having 1,000 horse-power or over, was reported by 59 companies. The use of small machines still predominated, more than three-fourths of all the machines being rated at 500 horse-power or less, their combined horse-power being 422,924, or 43.5 per cent. of the total for all classes. The detailed statistics of alternating current are presented in a supplementary table. There were 441 alternating-current generators reported, with a total of 231,924 horse-power. These machines were used by 163 companies, and of this number 128 reported that current was generated for sale for light or power. Considering all machines of this style, the average horse-power per machine was 526. There were 22 machines for each of which the indicated power was more than 2,000 horse-power. There were 219 companies using auxiliary electrical equipment of some character and 105 which operated substations. The auxiliary equipment consisted of transformers, storage batteries, boosters, auxiliary generators, rotaries, and electric motors used in plant or substations for miscellaneous work.

The total kilowatt-hours and horse-power of current for the year and the average per day are shown for each company, with totals for each State and the United States. In a few cases this information was not available, and in others the companies were not in operation during the entire year, so the totals should not be accepted as exact. It appears that the power plants noted, doing an electrical service, reported an output for the year of 2,261,484,397 kilowatt-hours, or 6,249,910 kilowatt-hours daily, this being roughly but not exactly

equivalent to 3,018,320,717 horse-power-hours for the year, or 8,338,190 horse-power-hours daily. Hence the 1,204,238 horse-power of dynamo capacity would appear to be employed on the average as nearly as possible seven hours daily, which, all things considered, is probably very close to the mark.

The figures for line construction showed 21,920.07 miles of single track operated by electricity, of which 97.18 per cent., or 21,302.57 miles employed the overhead trolley. A large proportion of this was span wire construction. Wooden poles very largely predominated. There were 24,754.29 miles of feeder wire construction reported, of which 90.26 per cent. was overhead. There were 6,546.9 miles of duct ready for use, on 589.3 miles of duct; but only 2,411.07 miles of feeder wire was underground. The conduits comprised 3,905.1 miles of iron pipe.

No fewer than 66,784 cars of all classes were reported. There were 60,290 passenger cars and 6,494 cars used for express, work or other purposes. Comparing the number of passengers carried and the passenger-car mileage with the number of cars, it appears that each car carried on the average 79,774 passengers and traveled 18,001 miles during the year, or nearly 50 miles every day in the year. Of the passenger cars, 32,658 were closed and 24,259 open. Combination closed and open cars were reported by 106 companies, the total number being 3,134, of which 1,203, or 38.38 per cent., were used by 22 companies in California. Combination passenger and express cars were used by 99 companies, the number being 239. Cars used for more than one service were enumerated only once; for instance, cars carrying passengers as well as material and mail were classified as passenger cars. The use of express, freight or mail cars was reported by 206 companies. The 1,727 snow plows reported do not include snow plow attachment, but only snow plow cars. Similarly the 790 sweepers included only sweeper cars. Cars used both as sweepers and as snow plows were counted only once, either as plows or as sweepers. There were 50,699 cars provided with electrical equipment; and as the roads operated either in whole or in

part by electric power reported a total of 64,618 cars of all classes, the number having equipment of this character was 78.46 per cent. of the total.

Of the total car mileage, 1,099.256,774, the passenger cars traveled 1,085,397,802 miles, or 98.74 per cent., and freight, mail, or other express cars, 13,858,972, or 1.26 per cent. In computing the car mileage and the car hours, where a road operated one or more trailers, or, in some cases, a train of cars, the entire combination was considered as one car. The total, therefore, contains a certain amount of train mileage, and allowance should be made for this fact in considering the average fare passengers per car-mile and car-hour. The fare passengers per car-mile for all companies averaged 4.43, and ranged from 0.01 for the Chicago General Electric Railway Company, of Chicago, Ill., to 69.15 for the Monongahela Incline Plane Company, of Pittsburg, Pa. It was impossible to obtain information concerning car-hours from a large percentage of the companies. However, 389 companies furnished this information. Their total car-hours for the year amounted to 65,869,342, of which passenger cars formed 65,403,287, or 99.29 per cent., and freight, mail, express and other cars 466,055, or 0.71 per cent. The fare passengers per car-hour for the companies reporting both factors averaged 33.28. No fewer than 286 companies reported that they were carrying mail, and the companies in the aggregate reported the owning and operating of as many as 350 pleasure parks.

As to the lighting of the cars, there were 66,784 cars of all classes, of which 62,339 were lighted, and of these 55,673 had electric lights. If the lights were averaged at 10 to the car, it would represent nearly 600,000 lamps in daily service of that nature. More than half the cars are reported as being heated, and of these 19,021 or 63.07 per cent. were warmed by electrical apparatus, and 11,138 or 36.93 per cent. by stoves, hot water, etc. Nor is this all, for the Census Office was careful to inquire as to the extent of electric lighting in the shops, car barns, etc., of the street railway companies, and it appears that

no fewer than 5,282 arc lamps and 235,955 incandescent lamps were thus employed.

By making a separation of the roads it was found that about 300 companies could be considered as operating interurban lines. Their total single track amounted to 8,853.53 miles, and their total earnings from operation for the year to $41,099,987; total operating expenses were $26,135,031, the net earnings being $14,964,-856. The single track of these companies formed 39 per cent. of the total for all companies, and their operating earnings 17 per cent. of the total earnings from operation. The interurban traffic, therefore, formed in 1902 only a very small proportion of the total electric railway business. There were about 56 companies, with 3,212.75 miles of single track, that operated what may be classed as fast long distance interurban lines. Each of these companies operated at least 20 miles of road, the average length of single track per company being 57.37 miles. The maximum running speed outside city limits was at least 25 miles per hour. The total operating earnings amounted to $13,657,021, and the operating expenses $7,924,568, the net earnings being $5,732,453.

While there were 67 companies using animal power and 259.1 miles of track operated by such power, the greater proportion of the track was owned by companies which used other motive power on a portion of the line. There were only 53 companies which used animal power exclusively, and their single track amounted to 158.12 miles, being an average of about three miles for each company. It is strange that the New York City region, in which the most advanced electrical appliances are in use on the street railways, is also the home of the antiquated horse car. Almost half of the trackage operated by animal power is located in Manhattan, and the Dry Dock, East Broadway and Battery Railway is the largest road operated by a company using animal power exclusively. With the exception of New York, there were only six places in which more than five miles of track were operated by animal power in 1902. The cable, which fifteen years ago had such bright prospects, is now antiquated. There are only two street railways

operated exclusively by cable power. From the Census bulletin there appeared to be twelve roads of this character, but ten of them are inclined planes.

The street railways of the country gave employment to labor on a large scale. The companies were served during 1902 by 133,641 wage-earners, to whom they paid $80,770,449 in wages—a very large proportion of their total income of $247,000,000. There were also 7,128 salaried officials and clerks employed, to whom $7,439,716 was paid in salaries. It is interesting to note the wage scale.

RATES PER DAY (DOLLARS).	All classes.	Conductors.	Motormen.	Road and track men.	Engineers	Firemen.	Mechanics.	All other classes.
Total	94,874	31,869	32,412	9,926	1,534	2,344	6,753	10,036
Less than 0.75	137	27	50	22	....	9	5	24
0.75 to 0 99	589	58	8	451	3	7	16	46
1.00 to 1.24	2,719	899	884	477	5	76	83	295
1.25 to 1.49	4,468	1,046	1,123	1,368	39	135	195	562
1.50 to 1.74	15,361	3,948	3,339	4,505	104	469	896	2,100
1.75 to 1.99	15,198	5,426	5,481	1 280	89	637	1,062	1,223
2.00 to 2.24	39,678	17,059	16,665	1 229	295	770	1,707	1,953
2.25 to 2.49	10,421	3,124	4,325	384	187	171	1,017	1,213
2.50 to 2.74	3,262	192	291	162	274	48	936	1,359
2.75 to 2.99	1,045	17	7	8	115	1	427	470
3.00 to 3.24	1,061	18	98	32	169	1	240	503
3.25 to 3.49	294	....	....	....	79	10	88	117
3.50 to 3.74	343	49	134	2	40	6	34	78
3.75 to 3.99	84	6	7	3	10	2	25	31
4.00 to 4 24	145	....	....	1	94	2	12	36
4.25 to 4 49	12	....	....	2	5	....	....	5
4.50 to 4.74	25	....	....	....	9	....	6	10
4.75 to 4.99	7	....	....	....	4	....	1	2
5.00 and over	25	....	....	....	13	....	3	9

As to the use of the service by the public, it appears that in the United States in 1890 the average number of street car rides per inhabitant was 32. In 1902, under the electrical regime, it was 63, and in the North Atlantic States it had risen from 66 to 124. The traffic earnings of about $234,000,000, with a population in 1900-1 of 76,000,000, would make the average expenditure per inhabitant for street car travel of just over $3 per head. Accidents were quite numerous, there being 1,216 persons killed and 47,429 injured, of the killed 265, and of the injured 26,690 being passengers. The roads

carried 5,870,957,830 "passengers" of all kinds, of whom 4,809,554,438 paid full, while the others enumerated had evidently the benefit of free transfers—the flat rate of 5 cents, with free transfers to other lines, being a common and universal practice in America.

The effect of electricity upon the development of street railway traffic has often been referred to, but is again emphasized in the figures brought out by the 1904 edition of "American Street Railway Investments." This excellent compendium gives among other things a summary of the earnings of 310 street railway companies in the United States; and very interesting data are included. The number of those reporting receipts of over $1,000,000 annually has increased from 38 to 42, and all of these companies show an increase in gross receipts with one special exception. The average rate of increase in the receipts in 1903 over 1902 was in this group 7.1 per cent.; in the second group, including companies over $500,000, it was 10.7 per cent.; in companies over $100,000 it was 16.5 per cent.; in companies over $50,000 the increase was 9.5 per cent., and in the fifth group of companies, over $25,000, it was 14.4 per cent. The general average increase for 1903 over 1902 was 8.5 per cent. This is certainly a healthy rate of increase. The figures of the United States Census office showed that the gross receipts of all the street railway companies for 1902 were nearly $248,000,000. If the rate of 8½ per cent. increase be applied to this, the gross earnings for 1903 for the street railways of America would reach the sum of not far short of $270,000,000. There seems to be no limit, in fact, to the expansibility of the street railway industry under the regime of electricity; and as the years go by it will be very interesting to trace the effect of electricity in increasing the traffic of the steam railroads to which it is applied. It would appear, from time to time, that other modes of traction, like the automobile, for instance, or the bicycle, might have some effect on street railway traffic; and we are not yet very far away from the time when some street railway managers thought they were going to lose all their income because so many people had taken to riding bicycles to

and from business. The figures of street railway traffic, in fact, certainly keep pace with the growth in population quite steadily, and appear to have a further rate of development of their own, depending very largely upon the increase of facilities. The figures in New York City bring out such an idea and confirm it, especially as soon as the benefits of electricity are thrown into the scale. In 1884 the street car passenger traffic of New York City was barely 185,000,000 passengers, and in 1894 it was only a little over 245,000,000; but it had jumped at the beginning of this year to 612,000,000. There can be no question of the fact that the extension of electrical facilities had a great deal to do with the last enormous stride. Just at present the rate seems to have fallen off a little bit, but this is due again to the fact that the elevated railroads by the adoption of electricity have once more come up to the proper standard of efficiency and competition, so that their figures of traffic which in 1889 showed only 174,000,000 passengers, or almost exactly what they were eleven years before in 1888, had jumped in 1903, after the adoption of electricity, to 246,000,000. Thus, whereas on the elevated roads in the period from 1893 up to 1899 there was actually a steady decrease in traffic, since 1900 and with the employment of electric traction there has been a tremendous rebound, so that the increase on the system in 1904 was 14.51 per cent.

The figures have now been given in general, as well as in some detail for the five leading developments of electricity in the arts and industries. There are a number of other branches that can hardly be brought to statistical account. Some of them are still nascent, as, for example, the application of electric traction on the main steam railroads of the country. This work is referred to in other handbooks of this series. But there are well-established arts like that of electric mining. Statistics show that there are already 3,000 electric mining locomotives in the United States of America, while the single State of Illinois reported in 1901 that in 12 mines in that commonwealth over 2,700,000 tons had been hauled by electricity. Other mining development has been on a scale of equal development, as in the use of

electric pumps, fans, hoists, drills, etc.; while latterly electric placer gold mining has sprung up as an industry, over 40 dredges operated by electric power being now installed in California. In fact, it is largely on account of electric mining that much of the long distance power transmission of the Far West has been done. In fact, the longest transmission system in the world, from the Sierras across the State of California to San Francisco and the shores of the Pacific—232—has been developed by the Standard-Bays Counties Companies on the water powers at first utilized in a primitive way for mining purposes.

The use of electric motors in mills and factories and other industrial plants has virtually grown into a vast field of industry by itself. The revelations of the twelfth United States census were in this respect little short of extraordinary. In dealing with the manufactures of the country, no fewer than 512,254 establishments or factories came under consideration. The extent to which hand-power is still resorted to, evidencing the opportunity for small electric motors, may be inferred from the singular fact that of these half-million establishments only 169,409 reported power. In other words, in only 33 per cent. of the "shops" in the United States had it paid to install ordinary mechanical power, or a gain of only 5 per cent. in ten years. Steam continued, of course, to be the great primary power and had risen rapidly, being, as the report shows, not less than 8,742,416 horse-power in 1900 out of a total of 11,300,081 horse-power. This is 77.4 per cent., whereas in 1890 it was only 51.8 per cent. Water-power, on the other hand, has gone off; for, although it has risen in bulk from 1,255,206 horse-power to 1,727,258, the percentage of the total in 1900 was only 15.3 as compared with 21.1 in 1890.

It appeared further that the electric power owned and rented for manufacturing work was only about 4 per cent. of the total, the figures being 311,016 horse-power owned, in 16,923 motors, and 183,682 horse-power rented. But this showed a gain of 1,897 per cent. over the figures of 1890, when the electric motor had not fairly come in.

Moreover, the fact deserves note that, while electric power rented was 183,682 horse-power, all other power rented was only 137,369 horse-power. In the early days of the motor it was proposed to rent out all the motors as a means of introducing them, and the practice gained considerable vogue, but, as the above statistics prove, people now buy and own their own motors, and the companies are not burdened with an investment it would have been extremely difficult to maintain free from enormous risk of detriment and depreciation. What this would have meant may be inferred from the statement that in 1900-1 the New York Edison Company reported 50,634 horse-power of motors connected to its circuits, or thirty times as much as in 1890. At $75 per horse-power, this would imply an investment by the company of nearly four millions in machinery that it would have had to watch over widely scattered territory. Obviously the plan of selling motors outright has not checked their adoption, in view of such phenomenal increases. Just here it may be noted as further evidence of extraordinary growth in power service that in 1904 the Edison mains in New York are supplying not less than 85,072 horse-power to electric motors on Manhattan Island. A further illuminating fact is that in 1902 one of the larger electric manufacturing companies reported the production of 16,000 stationary power motors, and an increase in that year alone of 40 per cent. in electric motor drive equipments.

From the data above given an idea may perhaps be formed as to the range and scope of the electrical arts in America. A rough summarization of the figures may be given in conclusion. Five of the branches cited include 394,000 employees of all kinds. The amount of capital in the same branches reached $3,500,000,000. It would not be far out of the way to place the total number of persons employed directly by electricity in the Unites of America in 1904 at 500,000, and the capitalization of all the electrical industries at $5,000,000,000.

Bureau of Standards Buildings.

THE NATIONAL BUREAU OF STANDARDS.

THE Bureau of Standards was organized July 1, 1901, as one of the bureaus of the Treasury Department. On July 1, 1903, it was transferred, along with certain other bureaus, to the newly established Department of Commerce and Labor.

The functions of the Bureau of Standards are briefly stated in the Act of Congress by which it was established. The Bureau is to acquire and construct when necessary copies of the standards adopted or recognized by the government, their multiples and subdivisions; to make accurate comparisons with these standards of instruments and standards employed in scientific investigations, engineering, manufacturing, commerce and educational institutions; to conduct researches pertaining to precision measurements and to determine the physical constants and properties of materials. The Bureau is also to furnish such information concerning standards, methods of measurement, physical constants and the properties of materials as may be at its disposal, and is authorized to exercise its functions for the Government of the United States, for State or municipal governments, for scientific societies, educational institutions, corporations, firms or individuals, and, as a matter of international courtesy, sometimes serves foreign governments. No fees are collected for services performed for the national or State governments; from others a reasonable fee is charged.

Buildings and Site.

To carry out these functions adequately requires large, well-equipped and fully manned physical and chemical laboratories. To this end Congress has appropriated $25,000 for a site, $325,000 for two buildings, and $225,000 for apparatus and equipment. The site lies in the northwestern suburbs of Washington, about three and one-half miles from the Treasury and 1,000 feet from Connecticut Avenue, just north of Cleveland Park. It

is 350 feet above the Potomac, and is the highest ground in the vicinity. Complete freedom from the jarring of street traffic is assured, and magnetic disturbances due to the only electric railway in that immediate region are very slight. These buildings have been so planned and located that additional buildings may be added as they become necessary.

One building is completed and occupied and the other is nearing completion. The larger of the two buildings, which is called the physical laboratory, will provide for the greater portion of the experimental work, including especially that part which requires to be kept free from mechanical and magnetic disturbances, and to this end it will contain scarcely any machinery. It will also contain the offices for administration, the library, and a well-equipped chemical laboratory. The mechanical laboratory contains the mechanical plant, instrument shop and laboratories for the heavier kinds of experimental work, where considerable power or large electric currents are required. These two buildings are united by a spacious tunnel, through which the air ducts of the heating and ventilating system, steam, gas and water pipes, and electric circuits are to be carried from the mechanical to the physical laboratory.

Heating and Ventilation of the Buildings.

The heating and ventilating of a laboratory is a matter of first importance, and has in this case received especial attention. In heating a building by the double-duct system hot air from one duct is mixed with cooler, tempered air from a second duct in such proportion as to hold the temperature of the room constant, the proportions of the hot and tempered air being regulated by a pair of dampers, the latter being automatically controlled by means of a thermostat. Each room of a building, therefore, has its own supply flue, regulating dampers and thermostat. The latter may be set at any desired temperature within the range of the apparatus. If now in hot weather the hot-air duct of winter carries air taken from out of doors, say at 85 degrees F., and the tempered-air duct carries artificially cooled air, say

at 60 degrees, a mixture of the two may give a room temperature of 75 degrees when the temperature would otherwise be 80 degrees or higher. The thermostat will adjust automatically the proportions of cooled and uncooled air, so as to hold this temperature constant, thus preventing the usual gradual increase of temperature as the day progresses. By a readjustment of the thermostat any other constant temperature can be secured, provided it is within the range of the system.

Not only does this system make possible automatic temperature control in summer—a most important end in itself—but it also secures a humidity control. For by cooling air its moisture is partly removed.

With this system of heating in winter and cooling in summer, with automatic temperature control and excess of moisture removed by refrigeration, the double windows of the laboratory may be kept tightly closed, and an atmosphere favorable for experimentation secured at any time, summer or winter. The closed double windows will also effectually keep out dust and dirt, two of the enemies of the experimentalist. With gas, compressed air, vacuum, hot and cold water, ice water and distilled water always at hand; with cold brine, carbon dioxide and liquid air always available for low temperatures, and gas and electric furnaces available for high temperatures; with direct electric currents, at potentials up to 10,000 volts and currents up to 10,000 amperes, and still higher alternating voltages and larger alternating currents always available, it is believed that the facilities and appliances necessary for carrying on a wide range of experiments under favorable conditions will be fairly well realized.

The Mechanical Laboratory.

The mechanical laboratory is built of dark red brick, trimmed with Indiana limestone. The building is 135 feet long east and west, 48 feet wide at the ends, and 58 feet in the central portion. It stands on ground sloping toward the north, so that the basement story is wholly above ground on the north, but is only a few feet above ground on the south. An extension of the basement,

A Washington Residence—Secretary Hay's Home.

wholly below the ground level on the south, is 20 feet wide and projects 25 feet east and west beyond the main portion of the building. This increases the floor area of the basement by 50 per cent., affording ample accommodation for the mechanical plant on this floor.

The boiler room is 42 feet square and 19 feet high, the floor being 5 feet below the engine room floor, and, like the engine and dynamo room, it is lined with white enameled brick. Two water-tube boilers, of 125 horse-power each, have been installed, and space has been reserved for two others, giving a final capacity of 500 horse-power.

The Engine and Dynamo Room.

The engine and dynamo room is 87 feet long and has an average width of 24 feet. A 120 horse-power tandem compound engine drives two direct-connected dynamos of 37.5 kilowatts each, giving 300 amperes at 125 volts, and a 50 horse-power simple high-speed engine drives two direct-connected dynamos of 15 kilowatts each, giving 120 amperes at 125 volts. One-half of the room is occupied by a number of alternating current dynamos directly driven by electric motors. These furnish single phase and polyphase current for experimental purposes. There are machines with smooth-core armatures and specially shaped pole pieces giving sine waves, others giving distorted waves, and another, to give several harmonic components which may be combined in various ways to give different wave forms, is now in process of construction. On the south side of the engine room a switchboard carries the controlling apparatus for the dynamos and motors, for several storage batteries, and for distributing current to the various laboratory rooms of both buildings. Live and exhaust steam pipes, water pipes, air ducts, etc., are located in the sub-basement under the engine room floor.

The Refrigerating Room.

The refrigerating room is 41 by 18 feet, and contains an ammonia refrigerating machine having a refrigerating capacity equivalent to the melting of 30 tons of

ice in 24 hours. Liquid air and liquid hydrogen machines will be added in the near future. A large tank filled with calcium chloride brine is located in the sub-basement just under the refrigerating machine, and enables "cold" to be stored equivalent to ten tons of ice. This may be used at night or to supplement the machine in the hottest part of the day when desired.

The air-cooling chamber contains a set of coils of galvanized iron pipe through which cold brine is pumped, and the air to be cooled is blown over these coils. On one side of this room space is reserved for placing apparatus which it is desired to cool or to perform an experiment at the low temperature of this room.

The storage battery room is 61 feet long, and contains several batteries, which furnish current to motors driving alternators, ventilating fans, the machines of the instrument shop, lights in the buildings when the engines are not running, and current for experimental purposes.

The Instrument Shop.

The large room on the first floor just above the boiler room is the instrument shop. This is an important feature of any physical laboratory where research is carried on. Six lathes of different sizes and styles, a universal milling machine, planer, shaper, drill press, grinder, circular saw and other machines have been installed, and a complete equipment of hand tools provided. The machines are directly driven by electric motors, so that no overhead shafting is used. A stock room adjoins the instrument shop.

Direct and Alternating Current Testing Laboratories.

The heavy current testing laboratory is provided with four large storage cells, which, when joined in parallel, will give a current of 10,000 amperes at the one-hour rate of discharge. They will be charged in series and may be discharged singly or together in any combination. Ammeters, shunts and recording wattmeters for heavy current will be tested here. The adjacent room, which is directly over the dynamo room, is used for testing alternating-current instruments. This includes

an examination of their behavior on different loads, at different temperatures, with currents of different frequencies, different power factors, and different wave shapes. Complete specifications of these factors are supplied when desired with the results of the test.

On the second floor is another electrical laboratory for alternating and direct-current experiments, study of transformers, condensers and cables under relatively high electromotive forces. The adjacent room will contain transformers for obtaining still higher alternating voltages for testing insulation resistances; and instruments for measuring alternating voltages up to 50,000 volts or higher will be tested here. A storage battery of small cells, giving potentials up to 10,000 volts and currents up to 1 ampere at this voltage is to be installed. Two rooms on this floor are used for the photometric study and calibration of incandescent lamps, gas lamps, Nernst lamps, etc. Immediately above, on the attic floor, is a large room for arc-lamp photometry. The hydraulic laboratory extends through the second and attic stories, giving a maximum height of over 25 feet. It is used for testing gas and water meters, pressure gauges, anemometers, steam indicator springs, etc. Provision has been made for a mercury column in the elevator shaft, so that it can be observed from the elevator platform.

The Physical Laboratory.

The physical building, like the mechanical building, is built of dark red brick and Indiana limestone, the first story being entirely of stone and the upper stories trimmed with stone. The building is 172 feet long, 55 feet wide, and four stories high, besides a basement and attic. It faces the south, overlooking the city of Washington.

The corridor extends the entire length of the first floor; the exterior of the building is so designed that if in the future additional buildings should be needed they may be placed one on the east and the other on the west of this building and connected to it by an arcade opening into the corridor of the first floor. The basement is

City Postoffice.

excavated under the central portion of the building and under the corridor, the four large rooms at either end of the ground floor having concrete floors, upon which piers may be built as they are found necessary. In one of the basement rooms a storage battery will be installed; the others will be used as constant-temperature rooms for experimental purposes whenever they are needed. Only certain special kinds of work will require to be conducted in these basement rooms, as all rooms on the first and second floors will be practically constant-temperature rooms, having heavy walls and double windows and automatic temperature regulation.

The Pipe and Wire Shafts.

Between rooms 1 and 2, next to the outer wall, is a vertical shaft three feet square, extending from the basement to the attic. In corresponding positions in the other three quarters of the building are three similar shafts. All pipes for distributing gas, compressed air, and vacuum, hot and cold water, ice water, distilled water, cold brine, and all the electric wiring for lighting and experimental purposes are carried up through these shafts. A door opens into each shaft on each floor, making everything accessible without the main pipes and wires being exposed in the laboratories. On each floor branches are brought out from the water pipes to the sinks, from the air and gas pipes to work tables, and from the distributing wires in the shaft to a small switchboard, there being one such switchboard for each suite of two or three rooms in each quarter of the building. The wires joined to these local switchboards run to a main switchboard near the north door of the first floor, and thence trunk lines run through the tunnel to the distributing switchboard of the dynamo room. Thus, through these two main switchboards and a local laboratory board, any circuit in any laboratory room may be connected to any other circuit in any other laboratory room or to any battery or generator in the mechanical building. The storage battery in the basement will be so connected to the main switchboard that any number of cells from one to the total number may

be joined to any laboratory circuit, and an auto-transformer will similarly give any alternating voltage required. Alternating currents of different phases and frequencies may be had at any place by connecting to the proper machine in the dynamo room.

The Laboratory Rooms.

Rooms 1 and 2 will be used as research laboratories and for precise measurements in mass, length and capacity. Rooms 21, 22 and 34 will be used for testing weights and measures. Rooms 11, 12 and 14 will be used for research laboratories in connection with various methods of making precise mass, length and capacity measurements, including optical methods and optical instruments. Rooms 31 and 32 will be used as general research laboratories, especially for optical work. Room 23 will be used as a laboratory for testing watches, chronometers, clocks, tuning forks, and other timepieces.

Rooms 8 and 9 will be used for research in heat and the testing of thermometers and pyrometers for measuring temperatures outside the range of mercury thermometers.

Rooms 16, 17, 18 and 19 will be used for investigation and the testing of resistance standards, resistance boxes and shunts; standard cells, and instruments used in measuring resistance and electromotive forces.

Rooms 28 and 29 are to be occupied by the magnetic laboratory, and rooms 36, 38 and 39 are to be employed for the investigation and testing of standards of capacity and inductance and for studying problems in which capacity and inductance are involved.

Offices and Library.

The third floor provides space at one end for a lecture room, and two rooms for apparatus and supplies; at the other end for the library and reading room, and in the central portion for the offices of administration. These rooms were placed on the third floor in order to devote the two lower floors solely to laboratory purposes.

Room 60, on the fourth floor, will accommodate the work in mercurial thermometers, including ordinary,

precision and clinical thermometers. Rooms 69 and 79, at the east end of this floor, will be used temporarily as lunch rooms. The other rooms of this floor are being fitted up as a chemical laboratory, for work in analytical, physical and electro-chemistry.

On the fifth, or attic floor, are the photographic rooms and storage rooms.

Organization of the Work of the Bureau.

While the work of planning and building laboratories and designing and constructing the somewhat extensive and in many respects unique equipment of the same has been going on, the Bureau has been effecting its organization and developing its work in temporary quarters. When the Bureau of Standards was organized it superseded the office of Standard Weights and Measures and acquired its equipment; the old offices in the Coast and Geodetic Survey building were retained, and by the courtesy of the superintendent of the Coast and Geodetic Survey several additional rooms provided in the adjoining building. A year later a neighboring residence was rented and converted into a temporary laboratory and instrument shop.

In these temporary quarters the Bureau has not only gathered together a considerable equipment of apparatus and done a great deal of preliminary work, but it has done some testing for the government and the public and not a little research. The quantity of testing done has been limited partly by an insufficient force, partly by the incomplete equipment of apparatus, and partly by lack of space. The work of testing, however, has been rapidly increasing during the past year.

The Personnel.

The act establishing the Bureau provided for fourteen positions at an aggregate salary of $27,140. The next year (1902-3) the number was increased to twenty-four at an aggregate salary of $36,060. The third year (1903-4) the number was increased to fifty-eight, with an aggregate salary of $74,700. For the present fiscal year there are altogether in the Bureau seventy-one

U. S. SOLDIERS HOME.

positions, with an aggregate salary of $85,780. These positions are as follows:

One director, one physicist, one chemist	3
Four associate physicists, one associate chemist, seven assistant physicists, one assistant chemist	13
Fifteen laboratory assistants, two aids, one librarian, one computer, one draftsman	20
One secretary, six clerks, two messengers, one storekeeper, one messenger boy	11
Five mechanicians, two woodworkers, five apprentices, two laborers	14
One engineer, two assistant engineers, one electrician, two firemen, two watchmen, one janitor, one charwoman	10
	71

Appointment through the Civil Service Commission.

All positions in the Bureau are filled by civil service examinations, in many cases as the result of special examinations. An erroneous idea is more or less prevalent that even scientific appointments in the government are made on the basis of personal or political influence. Nothing could be further from the fact. The officers of the Bureau have in every case striven to select the best man that was available for any given position. These positions are permanent, the civil service regulations affording ample protection against loss of position without sufficient cause. Thus, while the interests of the government are protected on the one hand, the interests of the employees of the government are guarded on the other.

Three Divisions of the Bureau—Division I.

For convenience of administration the Bureau has been divided into three divisions. Division I is under the personal charge of the director, Professor S. W. Stratton; Division II is under the charge of the physicist, Professor E. B. Rosa, and Division III is under the charge of the chemist, Professor W. A. Noyes.

Division I comprises six sections, as follows:

1. *Weights and Measures,* under the charge of Mr. L. A. Fischer (Columbian University), who was for

many years connected with the office of Standard Weights and Measures. He is assisted by L. G. Hoxton (University of Virginia), R. Y. Ferner (University of Wisconsin), N. S. Osborne (Michigan School of Mines), L. L. Smith, and G. W. Eastman (M. I. T.).

2. *Heat and Thermometry,* under the charge of Dr. C. W. Waidner (Johns Hopkins University), assisted by Dr. G. K. Burgess (M. I. T. and University of Paris) and Mr. H. C. Dickinson (Williams and Clark University).

3. *Light and Optical Instruments,* under the personal charge of Professor Stratton, assisted by Dr. P. G. Nutting (University of California and Cornell), Mr. F. J. Bates (University of Nebraska), and Mr. B. J. Spencer.

4. *Engineering Instruments,* under the charge of Mr. A. S. Merrill (M. I. T.).

5. *The Office,* under the charge of the secretary, Mr. Henry D. Hubbard (University of Chicago), assisted by Mr. D. E. Douty (Clark University), librarian, six clerks and two messengers.

6. *The Instrument Shop,* with Mr. Oscar G. Lange, chief mechanician, four other mechanicians and two apprentices, and the woodworking shop, with two woodworkers.

Division II.

Division II comprises six sections, as follows:

1. *Resistance and Electromotive Force,* under the charge of Dr. F. A. Wolff (Johns Hopkins University), assisted by Dr. G. W. Middlekauf (Johns Hopkins University) and Mr. C. R. Thurman (University of Virginia).

2. *Magnetism and Absolute Measurement of Current,* under the charge of Dr. K. E. Guthe (University of Marburg, University of Michigan), assisted by Mr. C. M. Jansky (University of Michigan).

3. *Inductance and Capacity,* under the personal charge of Professor Rosa, assisted by Dr. N. E. Dorsey (Johns Hopkins University) and Mr. F. W. Grover (M. I. T. and Wesleyan).

4. *Electrical Measuring Instruments,* also under the personal charge of Professor Rosa, assisted by Dr. M. G. Lloyd (University of Pennsylvania), H. B. Brooks (Ohio State University), C. E. Reid (Purdue), and F. S. Durston (Wesleyan).

5. *Photometry,* under the charge of Mr. E. P. Hyde (Johns Hopkins University), assisted by Mr. F. E. Cady (M. I. T.).

6. *Engineering Plant,* under the charge of the engineer, Mr. C. F. Sponsler (Pennsylvania State College).

Division III.

Division III comprises the chemical work of the Bureau. At present the personnel of this division includes, besides the chemist, only the associate chemist, Dr. H. N. Stokes (Johns Hopkins University) and the assistant chemist, Dr. Waters (Johns Hopkins University). This work is relatively late in its organization, for the reason that the Bureau has had no place in which to develop a chemical laboratory. The new buildings are now ready and a complete chemical laboratory will shortly be installed in one of them.

The Visiting Committee.

The visiting committee is constituted as follows: Dr. Ira Remsen, President of Johns Hopkins University; Dr. Henry S. Pritchett, President of Massachusetts Institute of Technology; Professor Edward L. Nichols, Cornell University; Professor Elihu Thomson, Lynn, Massachusetts; Mr. Albert Ladd Colby, Metallurgical Engineer, New York.

These gentlemen meet in Washington at least once each year, and, after receiving a report from the director, make a thorough examination of the work of the Bureau. On the basis of this examination they present a report to the Secretary of Commerce and Labor, making such recommendations as they think proper. This committee has already been of much service to the Bureau, and it is believed that it will also serve a valuable purpose as a medium of communication between the scientific public and the Bureau.

WHITE HOUSE.

Publications.

The publications of the Bureau consist of (1) the Director's Annual Report to the Secretary of Commerce and Labor; (2) the Bulletin, containing papers by members of the Bureau, including scientific investigations and descriptions of methods of testing; (3) Circulars of Information, containing announcements regarding testing, schedules of fees, and special tables and articles of general interest.

The Scientific Work—Division I, Section 1.

The scientific work and testing which the Bureau is doing at present or for which preparations are in progress may now be briefly stated by divisions and sections under which the work is subdivided.

Weights and Measures, including the determination of lengths, masses and volumes.

The Bureau possesses at the present time two iridio-platinum copies of the international meter, to which all lengths are referred, and the apparatus for comparing other bars with them.

It will be remembered that in 1893 Congress adopted the international meter as the fundamental unit of length, continuing the ratio of the yard to the meter as 36 to 39.37. At the same time the international kilogram was adopted as the fundamental unit of mass. Thus the old standard yard of 1840 and the Troy pound of the mint of 1827 were superseded, and hence all measures of length and mass in either metric or English system are now referred to the international meter and kilogram.

The Bureau is at present prepared to determine the length of any standard from 1 decimeter to 50 meters, and also to calibrate the subdivisions of such standards and to determine the coefficient of expansion of the same for ordinary ranges of temperature. The Bureau is also prepared at the present time to compare base-measuring apparatus and steel tapes.

The tunnel connecting the physical and mechanical laboratories will be fitted out with facilities for comparing this kind of apparatus. This tunnel is 170 feet

long, 7 feet wide, and 8 feet high, and facilities will be provided for comparing tapes up to 50 meters in length and to lay out a base of the same length with an error not greater than one part in two or three million, over which base-measuring apparatus may be tested. Means will also be provided for raising the temperature to, say, 40 degrees C., and lowering to 10 degrees C., for the determination of temperature coefficients of apparatus submitted.

The Bureau possesses two iridio-platinum copies of the international kilogram and also the necessary working standards to verify masses from 0.1 milligram to 20 kilograms. The balances now on hand include a number of the best American and European makes.

Capacity measures from 1 milliliter to 40 liters may be standardized.

The determination of the density of solids and of liquids is a part of the work of this section as well as the testing of aneroid barometers.

The Bureau has been called upon to advise the officers of state and city sealers of weights and measures regarding the proper equipment of those officers and the methods to be pursued in performing their functions.

Division I, Section 2.

Thermometry and Pyrometry. Facilities have now been provided for the testing of mercurial thermometers in the interval —30 degrees C. to +550 degrees C. The testing of toluene, petroleum-ether and pentane thermometers, and copper-constantan thermocouples for low temperature work, will be undertaken in the near future, the range extending down to about —200 degrees C.

The standard scale of temperature adopted by this Bureau for work in the interval —30 degrees to +100 degrees C. is the scale of the hydrogen gas thermometer.

As primary standards the Bureau now has fifteen Tonnelot and Baudin thermometers that have been carefully studied at the International Bureau and also intercompared here.

As primary standards in the interval 100 to 600 degrees C. the Bureau possesses some specially designed platinum resistance thermometers, both of the compensated and potential lead type, together with resistance bridges and other apparatus designed to afford the highest accuracy and convenience in working.

As secondary and working standards in the interval 100 degrees C. to 550 degrees C., the Bureau has a number of mercury thermometers constructed of French hard glass and of Jena borosilicate (59‴) glass. Those intended for work above 300 degrees C. have the space above the mercury filled with dry N or CO_2 gas under pressure.

In the interval 0 degrees C. to —200 degrees C. the standard scale of temperature is again that of the hydrogen gas thermometer, and here also the platinum resistance thermometer serves to define the scale. As secondary and working standards in this interval the Bureau has a number of toluene thermometers and copper-constantan thermo-couples; and in addition some petroleum-ether and pentane thermometers for use as low as —180 degrees C.

The scope of the testing work in this field, which is rapidly increasing, is somewhat varied. It includes the certification of precision thermometers to be used in scientific work, the certification of standards used by makers of thermometers, of thermometers used in important engineering tests, and of special types of mechanical thermometers used in industrial operations. The testing of clinical thermometers forms an important part of the work of this section. Special apparatus has been designed and constructed to enable this work to be carried on with the greatest rapidity and precision.

Special facilities have been provided for high temperature testing, such as the standardization and testing of nearly all kinds of high temperature measuring instruments, including thermo-couples, platinum resistance thermometers, expansion and optical pyrometers; the determination of the melting points of metals and alloys; the determination of specific heats and coefficients

of expansion at high temperatures, and the determination of the calorific value of fuels.

For this purpose the laboratory has been equipped with gas blast furnaces; electric furnaces which will maintain for hours temperatures as high as 1,400 or 1,500 degrees C., constant to within a few degrees; electrically heated black bodies; and the necessary accessory apparatus, such as potentiometers, special resistance bridges, recording pyrometers, etc.

As primary standards for work in the interval 600 degrees C. to 1,600 degrees C., thermo-couples obtained from various sources are used. These couples are referred to the scale of the nitrogen gas thermometer by measurement of their electro-motive force at known temperatures, viz., the melting or freezing points of some of the metals.

The high temperature scale used by this Bureau is based on the melting and freezing points of the metals as determined by Holborn and Day, and is a reproduction of the high temperature scale used by the Physikalisch-Technische Reichsanstalt.

Division I—Section 3.

Light and Optical Instruments.—The work of this section has recently been inaugurated, but it cannot be fully developed until the Physical Building is occupied.

Investigations on electrical discharges in gases, to determine among other things the conditions necessary for producing a given spectrum by such a light source, and a careful study of polariscopic measurements, with special reference to the accurate determination of the percentage of pure sugar in a sample, have been carried on during the past year. The Bureau has also undertaken, at the request of the Treasury Department, to supervise the work of polariscopic analysis of sugar in all the custom houses of the country.

Division I—Section 4.

Engineering Instruments.—The work now being done in this section includes the testing of gas

meters, water meters, pressure gauges, speed indicators, cement testing, and testing the strength of materials, using for the latter purpose a 100,000-pound testing machine. This work was begun comparatively recently, but is progressing rapidly. The range of the work will be extended beyond that indicated above as fast as possible.

Division II—Section 1.

Resistance and Electromotive Force.—In addition to standard resistances and standard cells, this laboratory also tests precision resistance boxes, Wheatstone bridges, potentiometers, precision shunts, etc. Specific resistances, temperature coefficients and thermo-electric properties of materials are also determined. A considerable part of the work of this section consists in the verification of apparatus of this kind for the other sections of the Bureau.

For the present all resistance measurements of the Bureau are referred to the mean of a number of 1-ohm manganin standards, which are reverified from time to time at the Physikalisch-Technische Reichanstalt, and are therefore known in terms of the primary mercurial standards of that institution.

The construction of secondary mercurial standards, which after suitable aging change less than wire standards, has been begun and in time will be of service in fixing with the greatest possible accuracy the value of the 1-ohm working standards. It is intended as soon as possible to construct a number of primary mercurial resistance standards.

The set of manganin resistance standards of the Bureau consists of ten 1-ohm coils and four coils each of the following denominations: 10, 100, 1,000, 10,000, 100,000; .1, .01, .001, .0001, .00001, besides two 2-ohm, three 3-ohm, two 5-ohm coils and two megohm boxes, this giving in most cases two reference standards and two working standards of each denomination.

Special efforts have been made to secure the accurate comparisons of the 1-ohm coils with those of the other denominations, bearing the ratios of 1, 10, 100, etc.

THE LEE MANSION AT ARLINGTON.

For directly determining the ratio of two nearly equal coils a special set of ratio coils and a four-dial shunt box has been constructed which enables the ratio to be read off directly to parts in a million, the dials reading respectively .1 per cent., .01 per cent., .001 per cent., and .0001 per cent. Other special apparatus has been built or is under way for making precision measurements with a minimum of labor in the observations and computations.

A considerable amount of testing has been done by this section, chiefly resistance standards and resistance boxes, but including also a variety of other apparatus.

Division II—Section 2.

Magnetism and Absolute Measurement of Current.—The work of magnetic testing, recently inaugurated, is about to be enlarged. Two important researches, namely, a study of the silver voltameter and a redetermination of the electro-chemical equivalent of silver and of the absolute value of the Weston and Clark standard cells, have been under way during the past year. A new absolute electro-dynamometer is being built for the latter investigation.

Division II—Section 3.

Inductance and Capacity.—A careful study of mica and paper condensers has been made, including the measurement of their capacities by different methods, the effect of time of charge upon their measured capacity, and the determination of absorption, leakage and temperature coefficients. Condensers have been purchased from various makers in England, France, Germany and America, and comparisons made with a view of determining the best performance to be obtained from both mica and paper condensers when used as measures of capacity. Some very interesting and valuable results have thus been obtained. Two large air condensers have recently been constructed to be used as standards. A new form of rotating commutator for use in determining capacities in absolute measure has recently been completed in the instrument shop and has been used in this work.

A considerable number of standards of inductance have been acquired and a great deal of work has been done in comparing inductances and determining their values absolutely. The Bureau is now in a position to make accurate measures of both capacity and inductance and to compare and test condensers or inductance standards for the public. A considerable amount of testing of this kind has already been done.

Division II—Section 4.

Electrical Measuring Instruments.—This section includes both alternating and direct-current instruments (including instruments for measuring heavy current and high potential), except those precision instruments included in Section 1. Some testing of ammeters, voltmeters, wattmeters and watt-hour meters has been done for the public, but the principal work done so far has been preparatory. Many instruments have been purchased from the best instrument-makers at home and abroad, and other instruments have been designed and built in own our shops. Much of the apparatus purchased has been tested, and in some cases altered and improved, and methods of measurement have been investigated.

In addition to direct-current generators and storage batteries, the following equipment of generators for alternating current has been acquired:

1. A small 120-cycle alternator, single-phase, suitable for voltmeter or condenser testing.

2. A three-phase 120-cycle alternator driven by an inverted rotary used as a motor and itself capable of giving a three-phase 60-cycle current.

3. A pair of 60-cycle three-phase revolving field alternators (direct-connected to a driving motor), of which one can have its armature rotated by a hand wheel while running, so that its current is displaced in phase with respect to the other. Using one of these generators for the main current (which by use of transformers may be multiplied at reduced voltage) and the other for the potential current, any desired power factor may be obtained and wattmeters and watt-hour meters conveniently

tested up to a capacity of 1,000 amperes and any desired voltage.

4. A pair of two-phase alternators, surface-wound, and giving currents of nearly sine wave form (direct-connected to a driving motor), one alternator giving 60 cycles and the other 180, arranged so that the two armatures may be placed in series and the wave form varied through a considerable range by varying the magnitude and phase of the third harmonic. This is useful in studying the effects of varying wave-form on the indications of measuring instruments of different kinds. For studying the effects of variations of frequency the speed can be varied between wide limits, and for higher frequencies the higher frequency machine may be used alone. Transformers are arranged to change these two-phase currents to three-phase when desired.

5. Another three-machine set has recently been added to the equipment. This contains two 60-cycle three-phase alternators, with adjustable phase relation and surface windings, giving nearly sine wave form.

Special attention has been given to the matter of accurately measuring frequency, phase and wave-form, as well as alternating voltages, currents and power. These latter quantities are measured by means of instruments which admit of accurate calibration with direct currents and electromotive forces, the latter being measured by potentiometers, using standard resistances and Weston cells, the e. m. f. of the latter being, of course, known in terms of the standard Clark cells of the Bureau. Thus all current, voltage and power measurements, both direct and alternating, are referred to standard resistances and standard cells.

The alternating instruments employed are as free as possible from errors due to inductance, eddy currents and capacity. Corrections are applied for the effects of small residual inductances when necessary. The alternating generators employed are driven by motors operated from storage batteries, enabling the speed and voltage to be maintained very uniform and measurements to be made with great precision. Thus frequency, volt-

age, power factor and wave form are controlled and varied as desired, and every effort is made to secure accurate measurements.

The Bureau is now prepared to test alternating voltmeters, ammeters or dynamometers, wattmeters, watthour meters, phase and power factor meters, frequency indicators and other similar apparatus.

In the testing of direct-current instruments the Bureau is now prepared to handle apparatus of capacities up to 1,000 amperes and 1,000 volts. A larger storage battery is being installed which will give currents up to 5,000 amperes at 4 volts, or 10,000 amperes at 2 volts, and a high potential battery of several thousand volts will be installed in the near future.

Divison II, Section 5.

Photometry.—After doing considerable preliminary work, the Bureau is now prepared to test and certify incandescent lamps to be used as standards, and has already done a considerable amounut of testing of this kind for manufacturers and others.

A considerable number of incandescent lamp standards have been obtained from the Reichsanstalt, the ratio of the candle to the Hefner unit being taken as 1 to .88. These reference standards are, of course, only occasionally used, and the mean of the values of several 16-candle power lamps is taken as the standard of the Bureau. Exact copies of these will be added from time to time, so that if a change in any lamp is detected it may be discarded without impairing the completeness of the set. The current and voltage employed in testing lamps are measured by a potentiometer and can be maintained very constant. Working by the substitution method, it is possible to make very accurate comparisons and thus to secure very exact copies of the standards of the Bureau.

The purpose of the Bureau is not to undertake, at least for the present, the commercial testing of incandescent lamps (apart from the testing done for the government), but to verify lamps to be used as standards and to make special investigations of lamps submitted

for the purpose. To this end no effort will be spared to maintain reliable standards and to certify copies with the highest possible precision.

Division III—Chemistry.

As already stated, the chemical division was late in being inaugurated. Aside from the immense assistance which a chemical laboratory can render to physical investigations, the division of chemistry will have important functions in its relations to the chemical interests of the country, and to the customs service and other departments of the government. Some chemical work is now being carried on, and detailed plans are being developed for the chemical laboratory immediately to be installed in the physical laboratory now approaching completion.

The Exposition Laboratory.

In addition to the exhibit which the Bureau is making in the Government Building at St. Louis, it has undertaken, at the request of the authorities of the Exposition, to install and operate an electrical testing laboratory in the Electricity Building during the Exposition. The work to be done will include the verification of measuring instruments to be used by the International Jury of Awards in testing electrical machinery and the testing for this jury of instruments and apparatus submitted by exhibitors in competition. It is obvious that the intrinsic merits of an electrical instrument cannot be entirely determined by inspection, but only by rigorous test, and that a fully equipped testing laboratory can render important service to a jury of awards in the important and responsible duties which the latter is called upon to perform.

This laboratory is located along the east side of the electricity building, south of the east entrance. The space assigned to it is nearly 200 feet long by 23 feet wide. A series of rooms have been constructed, all of which, except the office, have been equipped for laboratory purposes. A refrigerating machine having a capacity equivalent to the melting of ten tons of ice in twenty-four hours, installed by the Carbondale Machine

Company as an exhibit, is being used in connection with the ventilating machinery and heat-regulating apparatus to control the temperature and humidity of the atmosphere in the laboratories. Piers and other substantial supports for apparatus have been installed, and every effort has been made to provide the facilities and apparatus necessary to do precision testing.

In addition to doing the official testing for the Jury of Awards, testing for others will be done as far as practicable. For such work charges will be made according to the regular schedule of fees of the Bureau. The laboratory also serves as a working exhibit, and visitors are admitted at certain specified times. For this reason the exhibit of the Bureau in the Government Building is largely historical and educational and mainly devoted to subjects other than electricity.

The Scope of the Work of the Bureau.

The intention of the Bureau is to provide every facility necessary for experimental work, both for research and testing, and to have a sufficient force of engineers, firemen, electricians and other assistants so that the service may be available at any or all times. The instrument shop is already well established, and the expectation is to keep it so well manned that any of the various sectional laboratories can be promptly served whenever the work of testing or research makes the services of a mechanician necessary.

It is the constant purpose of the Bureau to co-operate with instrument-makers and manufacturers, to the end that their output of instruments and apparatus may be improved. Not simply to certify errors or criticise results, but to assist in perfecting the product is the aim. In this work the Bureau has so far enjoyed the confidence and co-operation of manufacturers to a gratifying degree. It was largely to meet their needs that the Bureau was organized, and if by serving them the standard of excellence of American-made instruments and machinery is raised, the Bureau will have served the public also. In several specific instances a marked improvement of this kind is already seen, due directly to the influence of the Bureau of Standards.

The advantage to scientific men and engineers of having a place in this country where instruments and standards may be verified with the highest possible precision and at nominal charges, and where researches may be undertaken when necessary to answer questions arising in such comparisons is evident. It greatly facilitates precision work both in engineering and in research.

The Bureau is also fulfilling another of the functions mentioned in the act authorizing its establishment, in furnishing information on a variety of subjects included more or less closely in its field of activities. A considerable correspondence of this kind has grown up.

The functions of the Bureau of Standards are very broad and its possibilities for usefulness correspondingly great. It aims to do in its field what the Coast Survey, the Geological Survey and the Department of Agriculture are doing in theirs, and what the Physikalisch-Technische Reichsanstalt and the Normal-Aichungs Kommission are doing in Germany. To fully realize these possibilities will of course require a further increase in equipment and in personnel, and this, it is expected, will be realized.

TRANSPORTATION

AND

ILLUMINATION.

Here was Built the First Conduit Railroad.

FIRST of American cities to possess a complete, passenger-carrying, conduit-electric road was this city of Washington. The study of its antecedents, its birth, its troubles, its growth and its success would rival any novel in interest. For the purposes of this book a roughly-sketched historical outline must suffice.

It is reasonably certain that in everything pertaining to the adaptation of motive power for street railway purposes the city of Washington has been one of the most conspicuous centers of experimentation. The reason for this mental, financial and mechanical activity is found in an uncompromising public sentiment adverse to the overhead construction common to all cities on the continent, New York and Washington alone excepted.

Forty-two years ago the national capital made the acquaintance of its first street-railway company; a new venture, and for a long time most unprofitable. Then followed a quarter of a century of horse-cars; conductorless, one-horse cars in large percentage, yet affording facilities sufficient for the needs of a non-manufacturing and only partially commercial community.

During most of those twenty-five years there was no great suburban growth, but suddenly the farming region around the city (yet within the limits of the Federal District) was transformed into attractive subdivisions, bristling with wonderful crops of surveyors' pegs and liberally marked with investment-attracting signs. Beauty spots previously unknown to the public were cleverly exploited, while all the varieties of persuasion were strenuously operated to the end that thousands of charming homes dot the delightful country which stretches into Maryland and Virginia.

Cheap and speedy transportation was one of the primary essentials to settlement. That could not be furnished by horseflesh, so the railroad mind turned toward other, more modern and more rapid methods of "getting there." To think of cable for such a purpose would have been absurdly extravagant, so the overhead trolley was instantly agreed upon as the thing for the environs. When there was effort to extend poles and wires into the city proper then followed outcry and strife.

Allegations and pleadings in behalf of overhead construction were met with what proved to be an overwhelming combination of fact and argument presented by Mr. Theodore W. Noyes, associate editor-in-chief of "The Evening Star," who insisted that if a conduit-operated road could be commercially successful in Budapest there was no reason why a similar venture should fail in Washington. For years there was raging controversy and surprising influx of inventive suggestion. Storage batteries and pneumatic motors were among the more prominent claimants for recognition; both methods succeeded in achieving friends, creditors and many interesting collections of non-negotiable scrip and non-salable scrap.

Especially strong was the fight before the District and Appropriations Committees of Congress; the interested, the disinterested and the uninterested were heard fully and freely. All the ills common or ascribed to the exposed trolley-wire were duly and completely catalogued and published, accompanied by marginal references, foot-notes, fire-loss statistics and mortality tables sufficient to completely overthrow the cause of those who held the overhead trolley in high esteem as a rapid-transit method, but who were, perhaps, a trifle thoughtless as to the probable effects of obstructing poles and wires in the streets of the nation's most beautiful city.

Resulting from this struggle came legislation forbidding further trolley trespass and authorizing "any company authorized by law to run cars propelled by horses in the District of Columbia to substitute for horses

THE COSMOS CLUB.

electric power by storage or independent electric batteries or underground wire or underground cables moved by steam power."

Two companies—the Capital Traction and the Columbia—lost little time in accepting the statute. They proceeded to install the expensive and generally troublesome cable, preferring a demonstrated mechanical success to any of the partially developed plans with which their neighbor—the Metropolitan—was struggling. For the Metropolitan the cable was an absolute impossibility, its main line having a percentage of curves far beyond the economical capacity of cable power in street-railroad operation.

Meanwhile there had been fair trial of a conduit system on U Street and Florida Avenue, not by any means satisfactory, but sufficiently so to demonstrate for the first time in this country the workability of a modified Budapest idea. Radical defects in construction and insulation finally made the project inoperative just about the time when Congress stepped in to put the finishing touches to a distressing situation and, undesignedly, to compel the success which might otherwise have suffered long delay.

"The Metropolitan Company must abandon horseflesh as its car-moving power within two years, or forfeit its franchise," said the supreme Legislature, in effect. "Likewise," said the same body, a little later, "it must pay certain paving taxes which it declares it does not owe, or its charter will be forfeited within eighteen months."

For four years from the anti-equine provision there were experiments, controversies, threats and promises, until finally—late in the summer of 1894—a legislative agreement was set forth in an Act of Congress which formally required the Metropolitan Company to operate its cars by that underground system which the company, as the results of its experiments, believed to be the only system mechanically and financially capable. It was risky business, but the company won out.

And so it came to be that Washington was the first city in the Western Hemisphere to possess and be proud of a complete, smoothly-operating and public-satisfying conduit electric railroad.

Combination Train, Washington Railway and Electric Co.

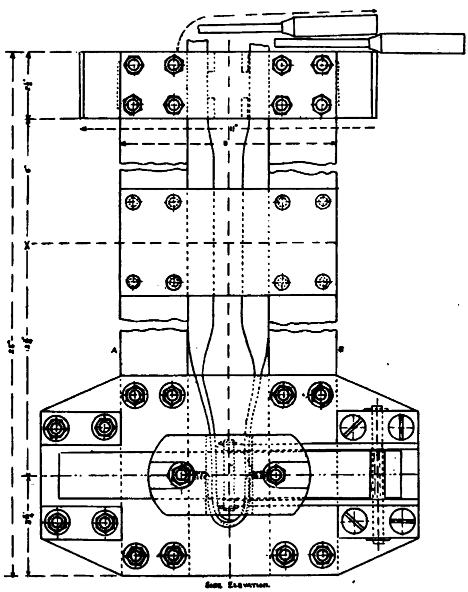
How the Washington Railway and Electric Company Came to Be.

"FIFTY millions of dollars have been added to the value of Washington and suburban real estate by the work just completed by the syndicated railroads."

That remark was made nearly four years ago by one of the city's most capable financiers—a man whose judgment as to real estate is as good as the best. No one seems to have estimated as to the added values since then, but it is certain that the increase has been steady and satisfactory.

Before the incoming of the Washington Traction and Electric Company—now the Washington Railway and Electric Company—there were many street-railway organizations; mostly disconnected, generally antagonistic, ancient as to equipment, wonderfully inclined to careless operation, devoid of transfer relationship and unable to gratify on a cash basis any considerable percentage of their creditors. There were some extraordinary and brilliant exceptions, of course, but there were so many corporate cripples, so many lean horses and shabby bobtail cars, so many agitating streaks of rust with divorced joints, so many crumbling roadbeds and rickety trestles, that the casual observer of the entire situation found it practically impossible to carry away an impression that would average as high as "good."

From any other point of view than that of the far-sighted and long-suffering railway investor the proposition was not attractive, but that kind of a man would not permit himself to be downed by little things, even if there were very many of them; so, with his mind made up, the investor reached out and secured eleven of the good, the bad, and the indifferent, as follows: The Metropolitan Railway Company, the Columbia Railway Company, the Anacostia and Potomac River Railroad Company, the City and Suburban Railway of Washing-



WASHINGTON RAILWAY AND ELECTRIC COMPANY'S STANDARD PLOW.

ton, the Brightwood Railway Company, the Washington, Woodside and Forest Glen Railway and Power Company, the Georgetown and Tennallytown Railway Company, the Washington and Rockville Railway Company, the Washington and Glen Echo Railroad Company, the Washington and Great Falls Electric Railway Company, and the Capital Railway Company. Also he secured control of the United States Electric Lighting Company and the Potomac Electric Power Company, believing that they might be operated in harmony with the railroads.

It was a bold venture. It would have been a bold venture had all the companies been in workable condition. The properties had not merely to be purchased; several of them had to be wholly rebuilt, while there was abundance of opportunity for necessary and expensive patching. More than four millions of dollars were spent in reconstruction. Large sums were disbursed in the rebuilding of the Brightwood and the Forest Glen lines. Then there was the reconstruction of the Georgetown and Tennallytown and the building of the Washington and Rockville. Steel bridges with stone abutments superseded the decayed trestle work on the Washington and Great Falls line, and the entire road was double-tracked. To catalogue the work done and to recite in detail the expenditures so liberally made would weary the reader.

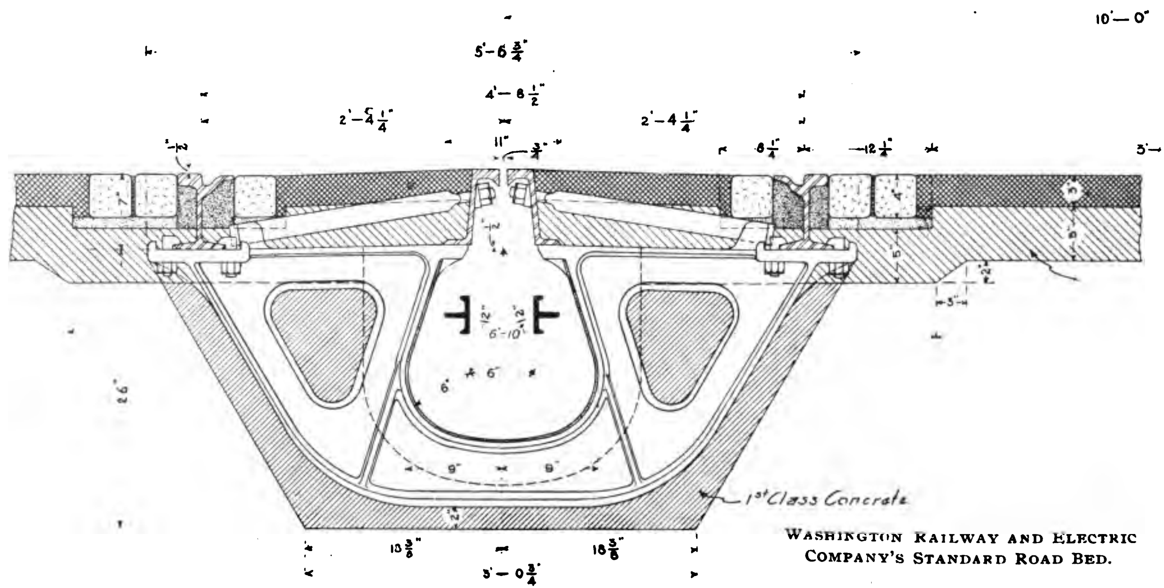
While the work of construction and reconstruction and repair was being pushed, strenuous efforts were also being made to adapt the equipment of the various lines to the uses of the companies and the patronizing public. In all the history of street railroading there was probably never such a museum of equipment as that which passed into the possession of the syndicate; every known variety of car, all the kinds of trucks, with motors ancient and modern and controllers ranging from the first and the worst to the last and the best. Then the methods of handling many hundreds of employes had to be systematized. Each road had been run after its own fashion, and sometimes the fashion was a very old one. The bringing of all these inharmonious

Standard Closed Car, Washington Railway and Electric Co.

elements—animate and inanimate—into some semblance of order was a tremendous task, that at times, especially when the financial conditions took a turn for the worse, seemed to be almost impossible.

Necessarily there was a great deal of experimenting, and some of this took place even before any serious effort was made to weld the lines into a system. Occasionally one of the experiments would prove successful from the popular point of view, but more frequently it met with so much disapproval as to cause the management much embarrassment. After a while there was a satisfactory condition, so far as roadways were concerned, and then there came betterment as to cars and equipment. Coincident with these things was the trying out of the transfer question, a problem of huge dimensions and filled with almost as many intricacies as there were passengers to be considered. As to schedules, there were many opinions, and as most of these were expressed in such a way as to attract the widest possible attention, the situation was both involved and noisy. Out of it all there came—and in such a short period of time that even the most critical were amazed—a system of transportation which is a surprise to every visitor and a gratification to every resident. Of course it is still short of perfection. It will always be more or less defective, because it is controlled by human beings, and perfection in human beings is not expected, but it will be better a year from now than it is to-day, and it will be better two years from now than it will be a twelvemonth hence. It is the plan of the management to steadily improve the rolling stock until the equipment is practically of one type. Even when that has been accomplished it is not supposed that it will result in expressions of unusual pleasure, but it is believed that the great majority of the public will be well satisfied.

No city in the United States has railroads which give to the public so much of a ride for so little money as Washington. For four and one-sixth cents a passenger can be transported comfortably and speedily from the northern boundary of the District to the southernmost railroad point 'way beyond Anacostia;

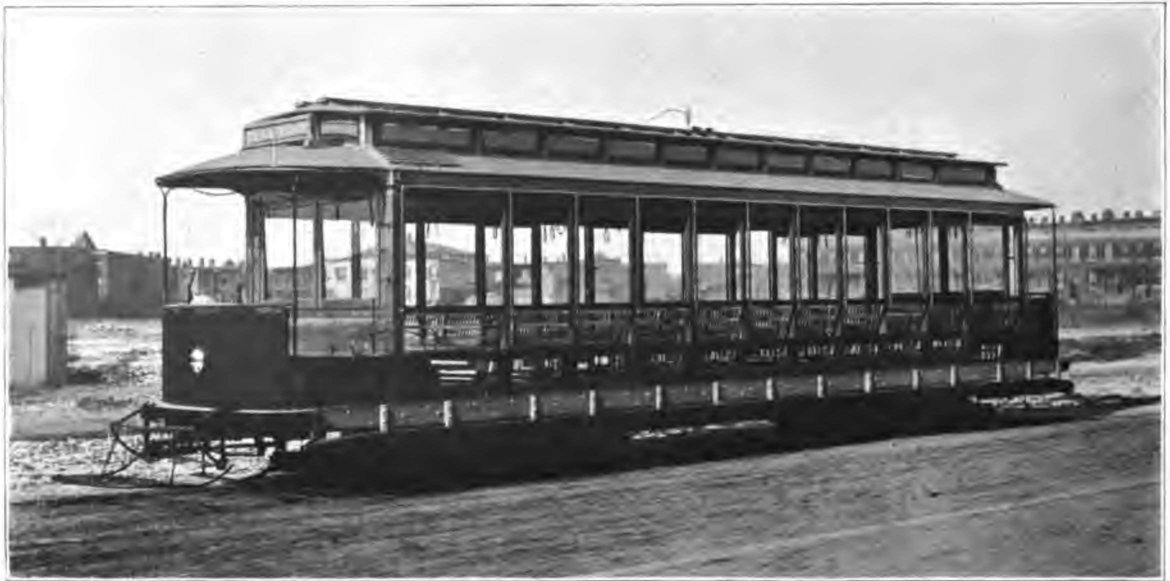


Section at yoke.

WASHINGTON RAILWAY AND ELECTRIC COMPANY'S STANDARD ROAD BED.

or from the District line on the east to the District line on the west. Such tremendously long rides for insignificant fares are not the result of Congressional enactment; they have been arranged by the companies because it is the plan to encourage riding. In other cities it may be possible to travel as far for five cents as one may travel here upon tender of one of the six tickets which may be purchased for 25 cents, but in no other city of long rides, except New York, is the passenger carried over an underground electric system which cost more than $100,000 per mile of double track. Elsewhere is the infinitely cheaper and esthetically less desirable overhead trolley, with its obstructive poles and exposed wires. Washington's streets are clear and its car service about as near ideal as it could be at this time.

Within the city there is still room for something of extension. Recently the Washington Railway and Electric Company—which, while it controls all the railroads named at the outset, consists only of the old Metropolitan, Columbia and Washington and Great Falls companies—extended its Connecticut Avenue line to Park Street, Mount Pleasant, and now the Anacostia and Potomac River Railroad Company is extending its Eleventh Street line into Holmead Manor, so as to provide accommodations for what soon promises to be a thickly settled portion of the city. Away out in Maryland the tracks of the City and Suburban Railway connect with a line now running to Laurel, and probably soon to be extended through Ellicott City to Baltimore. The first electric line to Baltimore, however, will come into Washington over the tracks of the Washington Railway and Electric Company, and have its terminus at Fifteenth and H Streets northeast, from which point passengers will be conveyed to the various parts of the city over the lines of the system. All of these things mean much to suburban Washington, and they mean a great deal for the city and its business. The city merchant prospers because new customers are transported to his stores. The owner of outlying real estate achieves wealth because distance is annihilated by rapid



Standard Open Car Washingtoh Railway and Electric Company.

transit. The thrifty citizen acquires a home with comparative ease by moving a few miles out of town to a place where land is cheap and where buildings are less expensive because less pretentious than in the city. There is all-around prosperity, and the frequently abused railroad is, after all, one of the greatest of public benefactors.

Station B, Potomac Electric Power Company.

POTOMAC ELECTRIC POWER COMPANY.

UNTIL twenty-three years ago no effort had been made to use electric current for lighting purposes in Washington. Of course, there were laboratory experiments long prior to that time, and there was occasional display of individual interest when there came news of modern illuminating methods put in common practice elsewhere, but no one had made any commercial attempt at electric lighting within the District of Columbia.

That first effort doubtless dwells in the memories of many people. The Society of the Army of the Cumberland was holding its reunion at the national capital, and there was a great deal of public concern as to the proceedings of the society. Money was contributed by the citizens in order that the celebration might be completely successful. One of the projected plans of entertainment included the illumination of Pennsylvania Avenue from the Peace Monument to the Treasury Building. The idea aroused great enthusiasm and there was wholesale manifestation of interest in the work of suspending arc lamps above the center of the avenue at considerable intervals. A dynamo was imported for the occasion and was belted to an engine in a Thirteenth Street sawmill. When the appointed time arrived the avenue was thronged with people who were anxious to see the promised transformation of night into day. The transformation did not take place. All the way from the boiler room to the carbons there was all sorts of trouble, and the waiting multitude saw nothing more than an occasional glow or a sputtering succession of sparking efforts to do business.

Out of that very distressing failure came success. The very magnitude of the disappointment operated on a few minds with so much of force that in a little while there was organized a company whose members proceeded to wrestle with the many difficulties in the way of maintaining an efficient electric light plant.

That company went the way of so many companies, and a little more than a year thereafter was organized the United States Electric Lighting Company; when, for the first time, was the electric light proposition placed upon a business basis. It was a very small business, though, for at the first annual meeting the report showed that there were only ninety-one arc lights and one hundred incandescent lights in operation. Satisfied with the prospects, however, the company proceeded to increase its equipment and to reach out for business. The first was easy, so long as there was money available. The second was slow because there was popular timidity as to the electric current, and there was strong opposition from organizations interested in the burning of oil and gas.

From the outset the United States Electric Lighting Company was intent upon using only the most modern devices and methods. Realizing that the city was entitled to all possible consideration, it proceeded to lay conduits so that its many lines would be beneath the street surfaces. That was an extremely expensive proposition, but it was appreciated by the public and by all who believed in the beautification of Washington. To-day the company's conduit system is a model in every respect.

For about two years Pennsylvania Avenue had a monopoly of public arc lighting—lighting for which the company was not remunerated—and then a number of property holders and merchants on F street decided that arc lights were needed on their thoroughfare; so they subscribed a sufficient sum and thus made excellent showing of the spirit which gave to F street an unassailable business supremacy.

For two weeks in July, 1885, gas, oil and other ancient illuminants were temporarily in complete possession of the city, a fire having destroyed the lighting company's plant. Two weeks after the fire all of the principal lamps were again in operation, and before the close of the year there were more than two hundred arc lamps and nearly three hundred incandescent lamps rendering satisfactory service.

Since that time the growth has been steady. Changes of administration have occurred, old equipment has been replaced by new, building has succeeded building, until now the Potomac Electric Power Company—which has recently absorbed the United States Electric Lighting Company—supplies all of the power needed for electric lighting purposes and nearly all the power necessary for the operation of the railroads controlled by the Washington Railway and Electric Company.

As each individual railway company equipped its road electrically, a power plant was built for it, and when the roads now forming the system were consolidated, feeders were rearranged and plants interconnected in such manner as to produce the best obtainable results under the existing conditions. Railway generators were removed from the Georgetown Metropolitan Railroad plant to the lighting company's plant, at Fourteenth and B Streets northwest, which is very near the center of the city.

The 550-volt direct-current is furnished by (1) the old Columbia Railway plant at the extreme east of the city; (2) the plant of the old Metropolitan Railroad Company at the extreme south of the city, on Four-and-a-half Street southwest; (3) the plant of the Potomac Electric Power Company, located at the extreme west, at Thirty-third and K Streets northwest; and (4) by the plant at Fourteenth and B Streets northwest, which is a little west of the center of the city.

In addition, a substation in Washington Street, about a block from the Pension Office, contains a large storage battery and a switchboard so arranged that the substation is practically a "clearing house" for street railway current. Feeders from all of the plants and cable connections with all the near-by lines are brought to this switchboard, and it is here possible to tie together all of the lines electrically, with or without the battery, to use the battery to assist one or more circuits independently, or by means of a booster to assist any one of the main stations.

From the plant at Thirty-third and K Streets two-phase current is distributed to three substations located

Part of an Engine Room—Potomac Electric Power Co.

in the suburbs. These supply current for the operation of some of the suburban overhead trolley lines. The two-phase feeders also pass through the main substation in Washington Street.

The two-phase system of distribution is gradually being displaced by the three-phase system, current for which is furnished by a 2000-kilowatt turbo generator of the Curtis type, which was recently installed in the plant at Fourteenth and B Streets northwest.

Three-phase current will be transmitted to both lighting and railway substations, and is also converted into single-phase current for suburban lighting.

These plants, with their combined capacity of about 18,000 horse-power, turn the wheels that run on more than 160 miles of street-railway tracks and that operate incandescent lamps by the hundred thousand, more than a thousand street arc lamps, and independent motors aggregating nearly 5,000 horse-power.

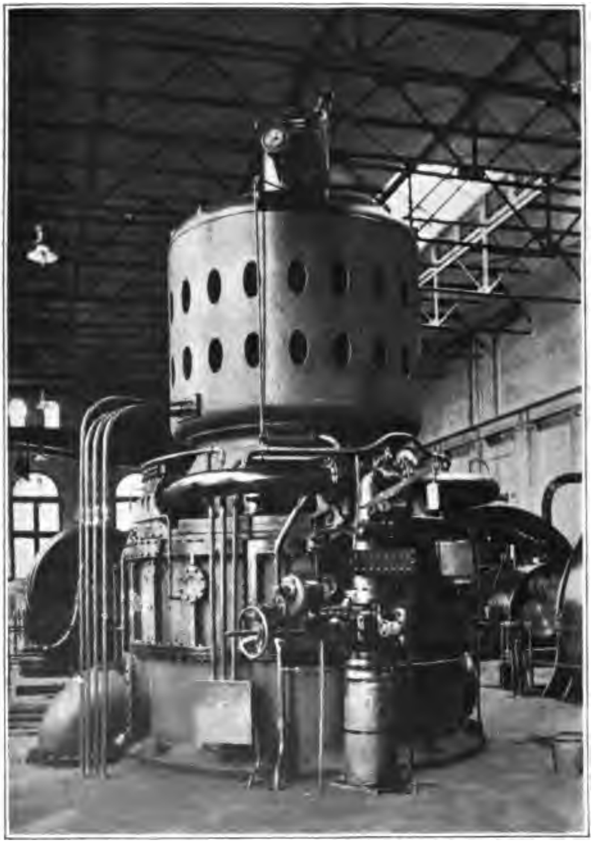
The increase in the utilization of the electric light and power is best shown by some comparisons between the output of the plant for several years back.

At the time of the consolidation of the two competing companies, in 1898, the total direct-current load was 11,000 amperes; one year later the peak load had increased to 18,000 amperes, and in December, 1903, the peak load was 32,900 amperes. During this period the suburban lighting by the alternating system also largely increased in volume.

The present lighting station at Fourteenth and B Streets northwest was new in 1897, and was designed with the idea that it would be ample in capacity for ten years at least. The new policy which was inaugurated by the officials of the consolidated companies resulted in an increase in output in the first year of 65 per cent., and in five years has shown that a new station on much broader lines must shortly be constructed.

The total connected horse-power in motors at present is 4,545. Total lamps connected, 201,706. Total equivalent connected load in 1901 was 150,000 16-candlepower lamps; in 1904 it is 277,000 16-candlepower lamps.

The current is transmitted through hundreds of tons



2000 K. W. STEAM TURBINE, POTOMAC ELECTRIC POWER CO.

of copper cable laid in conduits, the lineal measurement of which exceeds 1,250,000 duct feet. The big station is one of the show places of Washington for those people who can secure permission to inspect it.

These days, however, witness only the beginning of the electrical age in Washington. A short time ago the Potomac Electric Power Company purchased all of the rights and property of the Great Falls Power Company, and is now considering the development of the thousands of horse-power which have so long gone to waste a few miles above the city. With this combination of waterfall and steam harnessed together, the Potomac Electric Power Company proposes to make Washington an ideal city, both as to light and power. With the coming of the promised increase in facilities it would be unprofitable for any manufacturer in Washington to operate an independent steam plant, because the power company will be able to supply his needs at much less cost than they could be supplied by himself. To-day no residence is built without provision being made in its construction for those applications of electricity which give light and heat and which otherwise contribute to the comfort that is now a necessity.

Compared with other cities of the United States, Washington may fairly be termed "wireless." Through telegraph wires are still in existence on a few thoroughfares, and occasionally one may get a sight of telephone, electric light, police, fire-alarm or messenger service wires securely pole-strung, but within a very short period of time all wires owned by the telephone and electric light companies will be underground, leaving little more than the municipal copper overhead. That would not be so could the local authorities secure from Congress funds sufficient for that useful purpose.

The steady abandonment of overhead construction by the telephone and lighting companies is altogether voluntary. There was a time when it was necessarily not so, but now both of these corporations can afford to indulge in such operating luxuries (and ultimate economies) as conduits, and they are doing so just as

rapidly as any reasonable person could desire. Local public sentiment has expressed itself very strongly on the question of wires—ranging from the man who objected to them "because they make the English sparrows' feet sore" to the men who advance the best of reasons why the obstructions should be interred—so the corporate pride of Washington is doing large share of that work of public improvement which will soon make the nation's capital beautiful beyond compare.

THE SYSTEM OF THE CAPITAL TRACTION CO.

THE first street car service in Washington was begun in July, 1862, when the Washington and Georgetown Railroad Company ran its first horse cars on Pennsylvania Avenue. The Pennsylvania Avenue line has been operated without interruption since, and as the public's needs for service in other sections were manifested, they have been met by the other lines and various extensions.

When it became apparent that the horse car was not adequate, in the later '80's, the company considered what form of mechanical system would best meet the conditions. The overhead trolley system, then just beginning to be generally used, was properly not allowed in Washington, and the cable, the only other successful method of propulsion then available, was adopted. The Seventh Street line was first equipped, and immediately after that was put in operation, in 1890, work was begun on the other lines, so that August, 1892, found all the Washington and Georgetown Railroad's system operated by cable. This system continued to give satisfactory service until September, 1897, when the burning of the company's large central power station, at Fourteenth Street and Pennsylvania Avenue, put all the lines except Seventh Street out of commission. The fire occurred after 11 at night, but the disabled cable cars were hauled off the street and the trail cars started out with horse power on a regular schedule the following morning.

In the meantime the conduit electric system had been developed and proven satisfactory on the Metropolitan Railway Company's lines in Washington and also in New York, so the company's directors decided not to rebuild the cable power station, but to equip the entire road with that system. Fortunately, the concrete cable conduit was well adapted to the electric system, and work was soon begun on the track, power station and

STEAM AND ELECTRICITY.

From lunette painting by Frederick Dielman, one of the features of the mural decorations of "The Evening Star" Business Office.

cars, so that both the Pennsylvania Avenue and Fourteenth Street lines were electrically operated from the company's own power station in April, 1898. Parts of the lines had been run some months before that time.

The Seventh Street cable road was also rebuilt, the work being done without interruption to the cable system, which was driven by a separate station, now abandoned.

In September, 1895, the Washington and Georgetown Railroad Company and the Rock Creek Railway Company were consolidated under the name of the Capital Traction Company.

The Rock Creek Railway Company built its line from Chevy Chase Lake, Md., two miles beyond the District line, to the corner of Eighteenth and U streets, in 1892, using the overhead trolley. A year later it built an extension along U Street to Seventh Street, using the Love conduit system. This was among the first conduit electrical roads built and was probably the first to be regularly operated. It consisted of cast-iron yokes, 4 feet 6 inches apart, supporting the wheel and slot rails, and connected by a 19-inch conduit formed by cast-iron plates. The conductors were bare copper wire, suspended by composition insulators from the yokes, under U-shaped slot rails. The current was collected by an under-running two-wheel trolley. This road was operated until March, 1899, when it was rebuilt with the standard conduit electric system. It was operated in a fairly satisfactory manner, the difficulties being largely due to the flimsy construction of the road and the unsubstantial insulation.

The Capital Traction Company's system comprises the Pennsylvania Avenue, Fourteenth Street, Seventh Street and Chevy Chase Lines, fifteen and one-half miles of double track, conduit electric, and five miles of double track, overhead trolley line. These several lines operate between 90 and 125 trains, each train being usually composed of a motor car and a trailer.

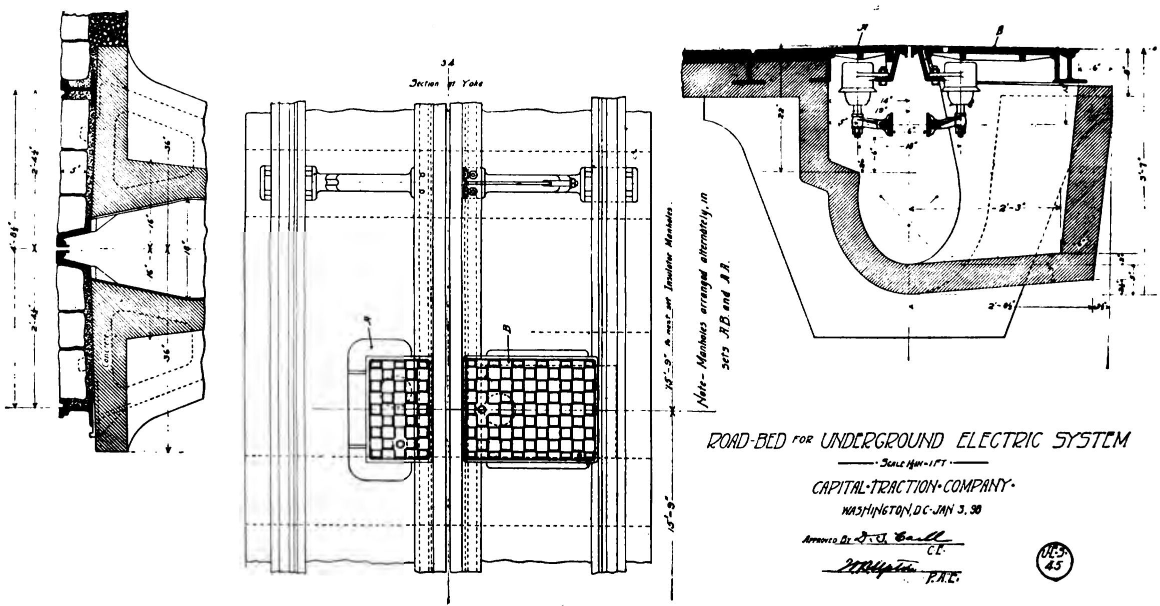

Section at Yoke
Note - Manholes arranged alternately, in sets A.B. and A.A.
ROAD-BED FOR UNDERGROUND ELECTRIC SYSTEM
CAPITAL-TRACTION-COMPANY-
WASHINGTON, D.C.-JAN 3, 98
Approved By
C.E.
P.A.E.

Fig. 1.

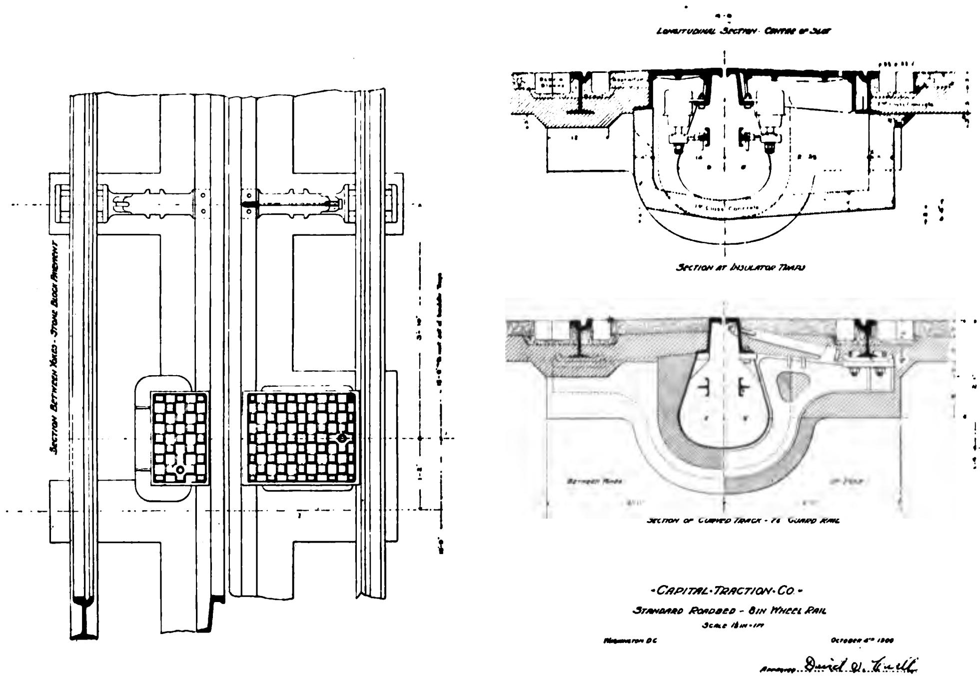
Road-bed Construction.

The conduit system is practically the same as that in use by the New York surface lines and the other lines in Washington. Power for the entire conduit system is furnished from a power station of 2,625-kilowatt capacity, located on the Chesapeake and Ohio Canal, between Thirty-second and Potomac Streets northwest. Power for the overhead line is furnished by a station situated at the northern terminus of the Chevy Chase line.

The conduit system embraces two standard types, one, including twelve miles of double track, is a reconstruction of the cable road, and the remainder was built especially for the electric system. The first (shown in Fig. 1) consists of a concrete conduit 36 inches deep with 6-inch wheel rail and slot rail supported on cast-iron yokes, spaced 4 feet 6 inches center to center. The T-shaped conductor rails, weighing 23 pounds to the yard, are supported by porcelain insulators whose cast-iron caps are bolted to the lower flange of the slot rail. The conductor rails are 31 feet 6 inches long and are supported at each end and in the center. Their joints are bonded with two 0000 flexible copper bonds.

In reconstructing the cable road for the electrical system it was thought best to provide a drip under the slot rail, so that surface water would fall to the ground at the slot between the conductor rails, instead of following the lower surface of the slot rail and falling on the conductor rails. To provide this, a small angle iron was riveted on the under side of the slot rail while in its position in the street. All sections of slot rail rolled especially for the conduit electrical system are provided with this drip rolled on the rail.

The only differences between the company's present standard construction and the reconstructed cable road are in the details, the depth being 25 inches instead of the 36 inches which was necessary for the cable road, and deeper rails are used, 8-inch for wheel rail and 7-inch for slot. The deep conduit has unquestionably considerable advantages, due to better drainage facilities and less liability to short circuits from wires or other



Longitudinal Section · Centre of Slot
Section at Insulator Thru
Section of Curved Track - 72 Guard Rail
Section Between Yokes - Stone Block Pavement
·Capital·Traction·Co.·
Standard Roadbed - 8 in Wheel Rail
Washington D.C.

Fig. 2.

metallic wastes from the street. The standard construction as built for the electric system is shown in Fig. 2.

The conductor rail insulation has proved very satisfactory in the six years the Capital Traction Company's system has been in operation. The insulation is not high, there being an appreciable leakage over the surface of the porcelain insulators, particularly during and after rains, but it is quite substantial and there is no record of an insulator burning out except from mechanical injury or an arc forming near enough for the heat to crack the porcelain.

Power Station.

The Grace Street power station, which furnishes current for all the urban lines of the Capital Traction Company, is located on the Chesapeake and Ohio Canal, on which the coal is delivered in canal boats, and which furnishes water for the boilers and jet condensers. The building is a long, narrow one, not very well suited in shape for this purpose, but was in the company's possession at the time of the destruction of their cable power station, and required only minor alterations. It is of brick, with slate roof, and has one brick cross wall dividing it into two main compartments, one containing the boiler plant and coal bunkers, and the other the engines, electrical equipment and accessories. Coal is delivered in canal boats at the western end of the building, where it is hoisted in buckets and deposited through a weighing hopper and crusher to the coal conveyor and thence taken to the coal bins over the boiler room. Provision is also made to unload coal directly into two storage yards adjacent to the station building.

The coal conveyor was built by the Steel Cable Engineering Company, of Boston, Mass., and consists of four endless steel cables, ⅝-inch in diameter, to which are clamped at intervals of one foot cast-iron attachments which form axles for the wheels carrying the conveyor, and to which are bolted the pans and buckets, the latter swinging on pivots. The conveyor is carried on wheels 3 inches in diameter, running on a two-foot gauge track. The conveyor is driven by a shunt-wound 12 horsepower, 500-volt motor, and is used to remove ashes from

under the boilers, as well as placing coal in the bunkers. The coal bunkers are divided into three parts; the main bin is V-shaped and runs the entire length of the boiler room, delivering coal through measuring hoppers and chutes directly to the hopper over each grate; the smaller coal bunkers are also V-shaped and are situated over the back of the boilers. They are only used for storage purposes. The coal bins are supported on trusses erected on columns at the side walls and a row of columns down the center of the fire room. The bin walls consist of arches sprung between I beams. The arches are of concrete formed with a flat interior surface on corrugated iron arch plates, with a thickness of concrete at crown of arch of 3 inches. The total capacity of the coal bins is about 2,000 tons, with additional storage capacity of about 2,000 tons in the yards.

Boiler Equipment.

The boiler plant consists of eight boilers, arranged in four batteries. Each boiler is of 350 nominal horsepower and is of the Babcock & Wilson horizontal water tube type, manufactured by the Aultman & Taylor Machinery Company. Each boiler has a water heating surface of about 3,300 square feet, with grate area of 75 square feet. They are operated under a normal steam pressure of 140 pounds, and the tubes were originally tested under a hydrostatic pressure of 300 pounds. The gases from all boilers pass through brick flues to a centrally located steel stack 150 feet high by 9 feet internal diameter, lined with red brick. The chimney is anchored to a brick foundation built down to bed rock. Locke damper regulators are provided on each flue. The coal is delivered through hoppers in front of each boiler into Roney mechanical stokers, driven by small Westinghouse engines. These stokers have proved very satisfactory with the George's Creek semi-bituminous coal, giving good combustion, with practically no smoke coming from the stack under ordinary circumstances.

Steam and Water Piping.

The boiler feed water is taken from the Chesapeake and Ohio Canal, flowing alongside the station, into a concrete well under the engine room, thence it is lifted

by an automatically controlled tank pump into a 4,000-gallon tank situated back of the boilers. From this tank the feed water passes through two Loomis-Manning filters having a capacity of 300,000 gallons in twenty-four hours, and from there it is forced by Deane boiler pumps through the heaters into the boilers. Provision is made for supplying water from the city mains into the tank, and an emergency water feed line is placed back of the boilers, supplied by two Metropolitan injectors.

The exhaust from each main engine passes through its own Berryman feed water heater to its own Deane jet condenser, thence through a cast-iron discharge pipe into the canal. An independent 14-inch spiral riveted exhaust pipe is also provided for each engine. The exhaust from the condensers, pumps and lighting engine all pass through a large Berryman heater situated in the boiler room. A space was left in the boiler room for an economizer, but none has as yet been installed, the flue gases passing directly to the chimney. The average temperature of the feed water after passing through the different heaters is about 181 degrees F.

The main steam pipe line is on the loop system, a main 12-inch header running the entire length of the building on the north side and an auxiliary 10-inch one on the south. These are connected at each end and also by an 8-inch equalizing main run along the dividing wall between the engine and boiler rooms. All bends in the steam mains are made on a long radius, and it was unnecessary to provide any expansion joints. Gate valves are provided in the headers, so that any unit, either engine or boiler, can be cut out and repairs made without interfering with the steam supply.

Engine Room.

The main generating units are five in number, each consisting of an 800 horse-power engine, direct connected to a G. E. 525-kilowatt, 600-volt generator. The engines are 20x40x42-inch tandem compound, running at 100 revolutions per minute, made by the E. P. Allis Company, with the well-known features of this type.

The generators are standard General Electric, eight-pole machines, compound wound, giving a voltage of 550 at no load, and 600 at full load.

As two of the feeder lines are quite long for direct-current work, their pressure is increased by motor-driven boosters. Three of these booster sets are provided, placed in the engine room between the main units; each consists of a 600-volt, 6-pole shunt motor, direct connected to a series generator, with a capacity of 550 amperes and 180 volts, giving a straight line characteristic from 0 to 100 volts when operated at a speed of 600 revolutions per minute.

The switchboard is about 50 feet long and is situated along the south side of the engine room about 5 feet from the wall. It consists of a standard panel for each generator, a total output panel containing wattmeter and ammeter; two panels for each pair of feeders; panels for each booster motor; two panels with switches, allowing either of the three boosters to be thrown on either of the two feeders whose pressure is to be raised; a rheostat panel; and a panel controlling the 600-volt lighting and power circuits about the building.

As the system fed is a metallic circuit with neither side grounded, equal switching facilities are provided for each pole of each feeder, and double-throw switches are used, so that the polarity can be reversed on each circuit. This is done to provide against short circuits which might occur from grounds occurring on different sides of two different circuits.

In addition to the 600-volt units, there is a direct-connected 50-kilowatt, 125-volt lighting set. This provides lights for the power station for the company's shops, which are situated across the canal, and also for the main office building and car barn a few blocks away. The station is well lighted naturally by numerous windows and artificially by numerous arc and incandescent lamps. Incandescent lamps on both 600-volt and 125-volt circuits are distributed over the whole building.

Lubrication of the bearings is taken care of by a gravity oil supply fed from a twelve-barrel tank suspended near the top of the end wall in the engine room. Cylinder oil is supplied to each cylinder under pressure through sight feed lubricators.

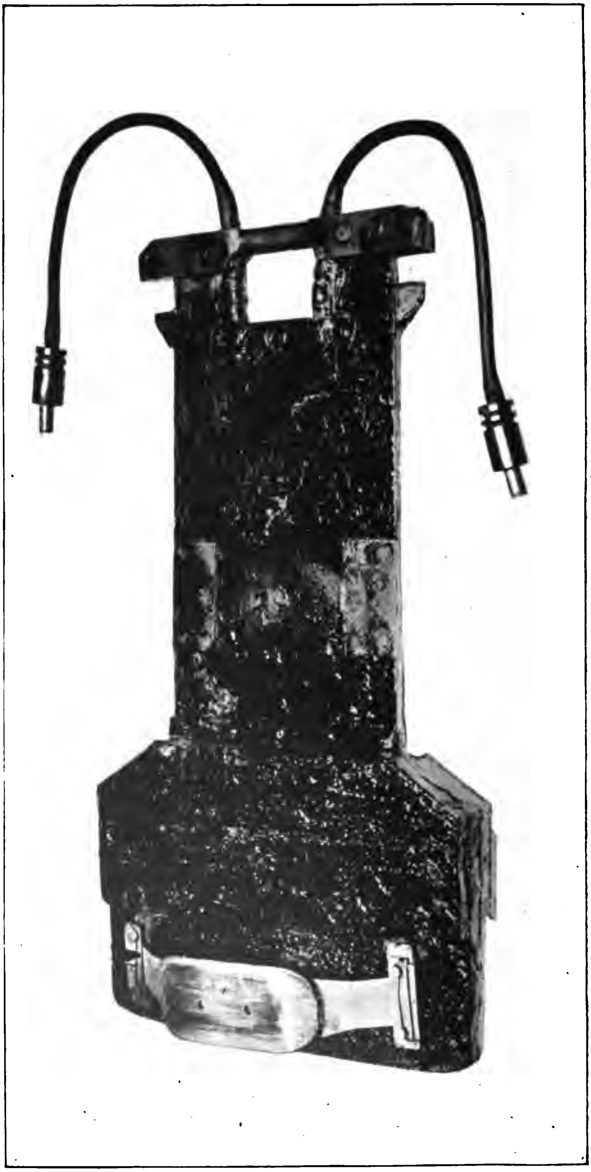
The engine room floor is of hard pine, laid on concrete arches, supported on I beams, which are in turn supported by the machine foundations and cast-iron columns. All foundations for main units and accessories are of brick extending to bed rock. A 15-ton, hand-operated crane spans the engine room, running the full length of the room.

The station, in addition to furnishing power for the company's entire city system, also furnishes heat and power for the shops.

Distribution System.

The distribution system consists of about 67½ miles of cables, having 3-16-inch paper insulation, protected by a ⅛-inch lead sheath. These cables, twenty in all, pass in racks under the engine room floor over the boiler room to underground conduits. The conduits are for the most part laid between the tracks and are part terra cotta and part cement pipes, with a sheet-iron covering. The latter have, however, proven very unsatisfactory and have given considerable trouble, due to corrosion of the lead sheaths of the cables. This has been especially marked through the low parts of the city, and recently about 3,000 lineal feet of terra cotta conduit has been laid to take the place of cement pipes.

A chloride storage battery is placed in the upper floor of the Mount Pleasant car barn, at the extreme end of the Fourteenth Street line, which is fed by a booster. This battery is of 320-ampere discharge capacity and consists of 260 cells, each cell having 9 plates with a tank capacity of 17. It is floated directly on the line without the intervention of a booster or any rotary machinery, and has been found in the two years it has been in service to be very economical to maintain and has satisfactorily served its purpose of taking care of the extreme temporary overloads which occur on this line.



Standard Plow—Capital Traction Co.
Fig. 4.

Car Equipment.

This company has not followed the practice of many of the American cities in using long eight-wheel cars, but their city equipment consists entirely of 20 to 26-foot cars, operated in trains of one motor car and one trailer. A complete equipment is carried of open and closed cars, both motors and trailers, and it has proven quite satisfactory on account of the flexibility of the service. Open trailer cars can be operated through a considerable portion of the mild winters Washington usually has, and they are quite popular with the road's patrons. This would, of course, be impossible with single cars, as a complete open unit would not be desired or permitted. The trailer system also makes it convenient to quickly change the service from open to closed cars at times of heavy summer rains. It has also been found that the train of two light cars is more economical of power than the heavier single cars, the average consumption on the whole line being 1.81 kilowatt-hour per train mile at the station switchboard. A view of one of these mixed trains is shown in Fig. 3.

All motor cars are mounted on "Lord Baltimore" trucks, each truck being equipped with two 35 horsepower G. E. 1,000 motors. All cars are lighted electrically and the closed motors heated in the same manner.

One of the most important parts of the equipment of the conduit electric system is the device used to convey the electricity from the conductor barns to the car, known as the plow. The plow used by the Capital Traction Company is the General Electric Company's Form 8, with several improvements suggested by experience. This plow is shown in Fig. 4. The two cast-iron shoes are pressed against the conductor rail by steel leaf springs. These springs are supported by iron yokes which are fastened to the maple plow bottom. This maple and a sheet of soft rubber give the necessary insulation. The current passes from the inner side of the shoe through a short piece of lamp cord used as a fuse to the lower end of the lead. The leads are continuous strands of copper wire running from the connector on

Combination Train—Capital Traction Co.
Fig. 3.

top to the fuse at the bottom. This wire is flattened out and reinsulated where it passes through the steel shank plates. Removable hardened steel plates are placed to take the wear where the shank passes between the slot rails. The plow is hung on two steel hangers attached to the truck, and is free to move laterally to allow for curves, etc. Should the plow take the wrong slot in passing over a switch, it slips off the end of the hangers, the connectors pull loose, and the plow may be removed without seriously delaying the movement of cars.

Shops and Barns.

The shops of the company are situated, as noted before, directly opposite the power station on the Chesapeake and Ohio Canal. They comprise three buildings, one of which is a storage barn containing a wheel-grinder and pits for removing wheels and overhauling and removing motors; another contains the wood-working and paint shops, and the third the forge room and machine shop. All motors are overhauled in the shops about once a month while in regular service, and all cars are thoroughly overhauled in all shops every year. All repair work is done in these shops, and occasionally new cars are built there.

Car service on the city lines is maintained from four barns, one at each end of the Pennsylvania Avenue line, one at the north end of the Fourteenth Street line, and another at the south end of the Seventh Street line. The Georgetown barn is three stories high; the other three, two. All are served by electrically operated car elevators and have suitable rooms for the train men and shops for minor repairs, as well as car storage facilities.

The company's suburban line, running from Cincinnati Street and Rock Creek to Chevy Chase Lake, is a double-track overhead trolley road with center pole construction, fed by a 750-kilowatt station at the northern end of the line. This station also furnishes lights for the village of Chevy Chase.

An amusement park at the Chevy Chase Lake furnishes an attraction for excursion traffic on this line during the summer season.

North Exchange Building.

THE TELEPHONE PLANT OF WASHINGTON.

WHEN the Washington telephone plant was first constructed, the whole conception of the scope of the service was very different from the present. Telephones were for the use of large firms, and for a few of the very luxurious in their residences. For the ordinary person it was an emergency service, to be used very much as the telegraph, when it was essential to communicate quickly. A great department of the Federal Government used only two or three stations, and, indeed, thought they needed no more. Public pay stations were few and far between, and it was often necessary to walk half a mile to reach one.

The plant required for such a system was extremely simple, judged by present standards. Ten years ago the prospect of more than one exchange for Washington had not even been contemplated. Except for a few of the main leads, nothing but open wire on pole lines was thought of. Even after the long distance lines were opened to Washington it was not expected that the average station would need to be equipped for such service, as the subscriber could go to the long distance office for the very exceptional out-of-town call.

The old carbon-button or Blake transmitter, with one cell of Le Clanche battery, was in general use; and the line, except for the short length in cable, was of iron and grounded. The magneto switchboard, with its large drops and jacks, was necessarily of small capacity. The drops were self-restoring, however, that is, the shutter was automatically closed when the operator answered, and as late as seven years ago this was considered the height of switchboard development.

Within the past decade, however, the whole conception of the use and place in our life of telephone service has undergone a complete change. The business had been developed along the old lines until the limit seemed

to be reached, and for a time growth was almost arrested. Then quite suddenly there was what might be called a *renaissance* in the telephone business. Pioneers here and there blazed the way, and showed a new place for the service in the affairs of men. Lower rate schedules were developed; the old, inflexible flat rates were superseded by equitable message rate schedules, under which each subscriber paid for what he got, and it became possible to offer rates which would appeal to the small user.

The demand for telephone service then grew faster than the plant could be provided. The idea was gaining ground that telephone service was for all classes just as distinctly as the mail service or the gas and water supply. The man who could not afford even the bottom rate should have access to a pay station within half a block and the privilege of calling for a nominal charge. This new idea demanded an enormous and very complex plant. A number of exchanges were required with provisions for trunking between; and as it became impracticable to carry the increased number of lines overhead, the subway system had to be greatly extended and enlarged. The old magneto station-battery plant could not be adopted to meet the new conditions.

The engineers, designers and makers of apparatus had kept pace with the development, and were ready to furnish new equipment of wonderfully improved character and most exquisitely adapted to the purpose in hand. It remained, however, to lay out a plant with due regard to present and future needs, and then construct it; and all this has taken, naturally, a good deal of time and money. It was necessary to plan as far ahead as possible, and then to build in such a way that no matter how or where the future development might come, in stations or in traffic, additions might be made as integral parts of the existing system and without sacrificing any part of it.

The study made as a basis for these plans was most thorough and very interesting. First, a large map of the city was carefully blocked off in various colors, each indicating a certain grade of business, residence or offi-

cial property. The number of existing telephones in each square was then set down, and a conference was held of a half-dozen people, each especially well equipped either from a business, a telephone, or a real estate standpoint, to determine the probable ratio of increase for each square during the following ten years. On the basis of the probable development so ascertained, assuming that 24,000 lines and, say, 60,000 stations would be required, the city was laid out in five exchange districts and a subway system planned which would be good for all time. The conduits which have already been built in accordance with this information reach nearly every improved square in the city, and in all congested districts are continued directly into the buildings, giving a house-to-house distribution entirely beyond the reach of storms or other disturbing influences. The ordinary practice in the residence section is to continue the underground cable to a cable box on a stout pole in the center of the square. From here it is distributed by short spans of twisted weatherproof wire to the rear of the houses. The short lengths of the spans and the fact that covered wire is used make line troubles almost unheard-of.

In four of the five city districts new exchange buildings have already been erected. Each has been designed especially for central office purposes, in accordance with the best telephone practice. All are of the most substantial fireproof construction, and heavy brick walls have been used in preference to the modern steel frame construction. The buildings have been designed, moreover, to bear the extraordinary weight of terminal apparatus, cables, generators, etc., on the top floor, and also to permit the erection of additional stories, if the growth of the business should require it.

Unusual precautions have been taken to insure dry walls, not only by courses of asphalted burlap in the foundations, but also by painting the inside with asphalt and then applying hollow terra cotta furring before plastering. Each building is amply supplied with well-designed outside fire escapes, and fire protection is everywhere provided. There is at least one stand-pipe

extending to the roof of each building. Normally the stand-pipe is connected with large tanks on the roof, kept full by electric pumps, which are automatically started the instant the water pressure becomes reduced. Sand buckets are plentifully supplied around the exchange and terminal rooms, and elsewhere in the building chemical extinguishers of the most improved type are at every turn.

The main exchange building, located in about the center of the city, is the last to be completed, and contains the company's general offices, as well as the central office, with a capacity of 10,500 lines. It is a six-story and basement building, about 50x150 feet in size, and is built of granite, white brick and terra cotta. The North exchange building, situated about one and a quarter miles north of the Main exchange, is of about the same dimensions and materials, except that it is only four stories high. The East and West exchanges, as the names imply, cover East and West Washington respectively. Each is of two stories and basement, and is built of brick, with stone trimmings.

The fifth central office, which is not yet built, is planned to be located about one mile north of the present North office, on the heights, where there is so much of present and prospective increase in residence service, and where the city must push out in the future.

A brief description of the North exchange, which seems in every way a model of central office and engineering construction, will suffice for all.

On the first floor of the building is an up-town business office, where patrons may pay their bills, make arrangements for service, etc. The entire second floor is used as a terminal room, and its generous dimensions, with ample light on three sides, make it unusually well adapted to the purpose. The steel frames, racks and cable runs were put in for the ultimate capacity of the switchboard during the construction of the building, and are bolted to the iron floor beams and to the ceiling beams above; they are thus virtually a part of the building and will carry the maximum weight and strain without sag or vibration. The 12 kilowatt motor generators

for charging the storage batteries, and the ringing machines, both in duplicate, are as solid and free from vibration as if built on rock.

In the terminal room the underground cables come up through a long, narrow brick shaft along the side wall to the base of the "main frame." In a fireproof trough under the floor, each cable is pot-headed and twisted and rubber-covered wire spliced on. These conductors are then led in a bunch along an arrester strip on the "main frame," where provision is made to carry to the ground any excess or foreign current which might come from the line. The wires are here cross-connected —in other words, their arrangement, which was geographical as they came from the underground cables, is changed to correspond with the numbers they are assigned in the switchboard. They are then carried in switchboard cables over light steel framing to the "intermediate distributing frame," which permits the distribution of lines for answering purposes among the various operating positions of the switchboard in such a way as to maintain a proper load at each.

Obviously the rate of calling in any group of lines is subject to great fluctuation, and it cannot be expected that the same number of lines which constitute a fair load to-day may be a fair load a month or six months hence. It is therefore necessary to have some method of giving part of the lines to another operator to answer without change of numbers, or, in other words, without altering their position in the multiple part of the board. This is accomplished through the intermediate. When it is considered that a uniform degree of high efficiency of operating is expected during the busiest hour of the busiest day in the year, it can be realized how important it is to provide a method for continually adjusting the number of the lines answered from each position.

In the terminal room are also located the racks of relays which operate the various lamp signals in the switchboard; the message registers which record the number of completed calls made by each message rate subscriber; the various generator units, and power

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switchboard; the storage battery which supplies all current for signalling the exchange, for operating the various switchboard signals, and for energizing the transmitters at the subscribers' stations; and the thoroughly complete test board of the wire chief and his assistants.

The floor above the terminal room is given up to operators' quarters, where every provision which careful thought can suggest is made for their comfort. A large, well-ventilated room is provided, with individual lockers of open metal work, in which each operator keeps her wraps and belongings, and where she leaves her individual telephone and transmitter when going off duty. Across the front of the building is a large lounging and reading room, well provided with easy chairs and couches. The tables are furnished with the latest magazines, and the operators on relief have full opportunity to refresh themselves in mind and body. Adjoining this room is a comfortable dining room, completely equipped with table service and with attractive buffet arrangements, from which tea, coffee and milk are served without charge. The company has taken account of the trying nature of the operators' work, and with the realization of the necessity for a contented, loyal body of employees, is leaving nothing undone which could contribute to the desired end.

Another room on this floor is now being used for an operators' school, which is in itself a very interesting institution. Of the many applicants for the position of operator, a few of the most promising are accepted as students and are given a thorough course of theoretical and practical training in this school. After graduation they are well equipped to take a place at any of the company's switchboards.

On the fourth floor is the exchange proper, and with its huge dimensions, lofty ceilings and abundant light, it would be difficult to imagine a place better adapted in any particular for the purpose for which it was designed. The switchboard, which is planned for an ultimate of 10,500 lines, is now equipped for 4,500. It is of the latest type of "relay" or "common battery" board, and strikes one as being almost human in its workings.

While frankly a manually operated board, it is so nearly automatic in its functions that the work of the operator has been reduced to the mere act of making the connection with the desired number and pressing the button.

At the cable turning section, where the cables come up from the intermediate frame, the board starts around the room in two directions, the "A" board, or subscribers' sections, proceeding to the left, and the "B" board, or incoming trunk sections, going to the right. The extent of the "A" sections will naturally depend upon the number of operators' positions required to answer the full number of lines provided for, which in turn depends largely upon the average of calling; but the growth of the "B" sections will depend upon the development of other exchanges and the consequent increase of volume of incoming traffic.

The familiar principle of multiple switchboards, which requires that every line shall appear in its approximate jack once in every section, or within the reach of every operator, there being three operators to each section, naturally fixes the limit of size of the switchboard in accordance with the size of the jacks and the compactness with which they can be placed in the board. The smallest jack now in use must be placed with incredible compactness when one considers that at least three wires must be soldered to springs in the rear of each, to permit the operator to reach ten thousand of them.

The process of operating, identical with that in all recent Bell exchanges, is briefly as follows:

When the telephone is lifted from the hook at the subscribers' station a tiny lamp is lighted just above the "answering jack" with which it is associated. The operator takes one of a pair of flexible cords and inserts the plug at the end in the answering jack indicated, automatically extinguishing the light, while with her other hand she has thrown a "listening key" connecting her with the calling party. In much less time than it takes to tell it she has ascertained the number wanted, tested the line to see if it was in use by touching the tip

of the other plug [illegible] the plug, pressed the [illegible] used, and cleared [illegible]

In the key shelf [illegible] board, there are two [illegible] cords. When the [illegible] scriber's jack, the lamp [illegible] mediately [illegible] answered. When [illegible] both supervisory lamps [illegible] nects both cords. [illegible] operator would know [illegible] talking the other [illegible] accordingly.

Selective [illegible] lines, and the [illegible] ton, can call [illegible] other bells. [illegible] series [illegible] finds it necessary [illegible] pend on her memory [illegible] was wanted.

When a party [illegible] the operator [illegible] through what [illegible] the "B" operator [illegible] number. The "B" [illegible] if not [illegible] tween the two [illegible] the number of the [illegible] then connects the [illegible] trunk and the [illegible] erator presses the [illegible] down by a magnet [illegible] station [illegible] swered when the [illegible] hook [illegible]

Abundant [illegible] manager and [illegible] ture switchboards [illegible] tion" and [illegible]

TOMB OF WASHINGTON—MOUNT VERNON.

tion is kept posted up to the hour, and all inquiries as to new subscribers, changed lines, toll calls, etc., are promptly handled. Records are kept of every station alphabetically according to subscribers' names, numerically, according to the call numbers, and by street addresses.

Each group of eight operators is in charge of a supervisor, who is constantly on the alert behind her group, seeing that all calls are promptly handled, and taking over from the operator any troublesome matter which may arise. In charge of the supervisors is the chief operator, who in turn reports to the manager, who is held responsible for the efficiency of the exchange at all times.

The company's outside plant, as already indicated, is almost entirely underground. The cables are of the standard paper-insulated, lead-covered type, with usually 400 pairs of wires each. Each pair of wires is twisted at different intervals, and the separate pairs are laid up in a spiral fashion, the number of turns in a given length being determined with mathematical accuracy. Many of the cables terminate in multiple, so that any number of conductors may be used at any one of the several terminals, thus requiring a minimum of idle plant. In some sections, where the requirements are still light, the lines are run in aerial cables of from 25 to 100 pairs, and these also open in the multiple at various points, in this way requiring very little open line even in the outlying sections.

All station equipment is of the latest Bell type. A very large proportion of the stations are equipped with desk stands, and this attractive and convenient form of apparatus is seen wherever one goes. The desk telephones are usually wired as extension stations from the main telephone, which is centrally located for general use. It is frequently desired that all calls shall be received at the main station, and that the extension station shall only be signalled when the individual there is wanted.

PRIVATE BRANCH EXCHANGE.

From one or two extension telephones the service naturally grows to a private branch exchange, or, as a recent writer termed it, "a satellite exchange." In this system the principle of the exchange is applied to the subscriber's premises. As many stations as may be required, on or off the premises, are wired to a small switchboard, which in turn is connected with the public exchange by two or more trunk lines. The whole is ideally flexible and can be adapted exactly to the subscriber's particular needs in every direction.

The operator at the private branch exchange is one of the greatest business aids of the day. She not only facilitates outgoing traffic, but acts as a most admirable selector and distributor of incoming calls. The advantage of having these calls always answered by a courteous, trained telephone clerk, instead of by any one who happens along, is being more and more generally appreciated. The internal traffic between the several stations of a private branch exchange is also of very great value in the conduct of any business. Private branch exchange service is seen everywhere in Washington. Hotels and apartment houses are practically all so equipped, and, indeed, a telephone has come to be as much expected in a hotel room or in an apartment as electric light and steam heat. Thirty per cent. (30%) of all telephones in Washington are connected with private branch exchange switchboards. This proportion is exceeded in only one city in the world.

An interesting feature of the business in Washington is the service supplied the Federal Government. Each department has a complete private branch exchange system, designed especially to meet its various and individual requirements. In some cases the situation is met by a large number of telephones, all connected to one switchboard; in other departments there is one main switchboard with several subsidiary switchboards in the various bureaus, each connected direct to the exchange of the telephone company, and all tied together with internal trunks. The residences of some officials are connected with their department boards. There are also direct lines from the various private branch exchanges

to the office of the long distance company, thus securing direct connection for long distance calls. The various departments of the Government are also connected with each other by "tie lines."

The result is a great self-contained system of over two thousand telephones, ideally meeting every possible demand for departmental and inter-departmental communication, as well as for local and foreign telephone service. The President can sit at his desk and be in instant communication with any member of his Cabinet or with some one a thousand miles away. The head of a department can confer in a moment with his lieutenants in Washington or at distant points; and clear down the line to the lowest clerk, business can be expedited in a way which was not dreamed of ten years ago. It might almost be said that the telephone wires are the nerves of the Government, enabling an impulse at the head to be felt instantly at the very extremity.

For the stranger, for the passer-by, for the man who cannot afford service, pay stations are everywhere, varying in facilities from a single telephone in a corner drug store or grocery, attended by the proprietor, to the large installation in hotels, railway stations and other public places, equipped with several lines and booths, and attended by the company's operators and messengers.

In the country surrounding Washington a number of small exchanges have been established, with the object of completely covering the telephone field not only by meeting every present demand, but by placing facilities in advance of the requirements. To exchanges located outside of the District of Columbia a small toll charge is made. No additional charge is made, however, for calls to any exchange located in the District. Ample facilities are provided for talking with all long distance points, and thoroughly efficient service at moderate charges has made the familiar phrase, "Don't travel—telephone," a household word.

The company's rate scheme has gone through a gradual evolution, and now seems as reasonable and flexible as can be expected under the present conditions. Business service is rendered only on the message basis, now universally regarded as the one equitable plan. The rate per call decreases as the number increases up to four thousand messages a year, which is considered the maximum number of out-going calls which can be sent, with due regard to the use of the line for incoming service. Flat rates are still offered residences, as the use of residence telephones is never excessive, and there is no danger of the line being used continually for outgoing traffic to the exclusion of incoming calls.

The Chesapeake and Potomac Telephone Company is working constantly and with unceasing energy to supply a thoroughly efficient service at reasonable rates for every possible demand, and at the same time it is diligently preparing amply for all future requirements, no matter how rapidly they may develop.

The American Telephone and Telegraph Company (long distance) has its Washington offices at the corner of Fifteenth and F streets northwest.

At these offices the company maintains, in addition to its operating room, a group of pay station telephones, each telephone in a sound-proof booth, for the use of the general public.

The company also has trunk lines connecting its switchboard with the different exchanges of the Chesapeake and Potomac Company, thus enabling the subscribers to the Chesapeake and Potomac service to get long distance connections at their own telephone stations.

August 19, 1904.

U. S. PATENT OFFICE.

ELECTRICITY IN THE ARMY.

VON MOLTKE has said that war is the only science that lays under tribute all other sciences. Among all the other sciences used in the art of war, possibly none has had as extended an application in recent days as that of electricity. The electrical service of the army is divided into the service of communication, which includes all devices and apparatus for transmitting intelligence—the cable, the telegraph, the telephone, and wireless telegraphy. In the fortifications light is needed for the magazines and galleries, searchlights to illuminate the channels and cover the torpedo fields and for night signalling, and power to move the heavy guns, work the shot-hoists and all auxiliary machinery in the complicated plant of a modern fortification. After the various appliances and plants have been installed by the different supply bureaus of the service, the artillery is charged with their operation and with the working of the submarine mine fields. The Engineer Corps of the army constructs all the gun emplacements and mining casemates, builds and installs the power plants, and furnishes motors and accessories for operating the shot-hoists and the searchlights. The Ordnance Department, in addition to furnishing the armament, provides motor-controlled systems for elevating and training the guns in azimuth; and the Signal Corps of the army provides all the complicated apparatus for the system of fire control and direction of the batteries in addition to its work of being charged with the general system of field communication for the army. The engineering conditions under which electricity is applied are essentially the same as in commercial practice, but are prosecuted under conditions which of necessity must be more exacting and difficult. Efficiency and certainty of operation outweigh in the problem of design the cost of installation and economy of operation. Many inge-

nious means and methods of the application of electricity to the military service have been devised from time to time, but a large number proved of little value, as they have been either too complicated or too delicate. No device or apparatus which cannot survive lack of attention and skilled supervision, exposure to weather, rough handling in transportation, or the effect of the blast of heavy guns, will prove of value at the critical moment of its use at the time of actual battle.

Unfortunately for efficiency, the technical corps of an army is a very small proportion of its total strength, and the pay of the enlisted men is not sufficient to prove an inducement to men skilled in the use of electricity, who are much better paid for the same work in civil life, to enlist in our service. One of the greatest limitations of its development in the service has been lack of appreciation by Congress of its importance, and the consequent lack of necessary appropriations.

The Signal Corps of the army is charged with the construction, repair and operation of military telegraph lines, and the duty of collecting and transmitting information for the army by telegraph or otherwise.

While the importance and value of rapid means of communication in the commercial world have been demonstrated by the experience of over one-half a century, and the enormous amounts of capital invested in the telegraph, telephone and cable, such means of communication are absolutely essential to success in modern war, where time is one of the most important of controlling factors. Electricity is the most potent agent in our control to effect such a saving of time.

The service of communication in the Signal Corps is divided into field and fortress work. For field work the telegraph, telephone, cable and wireless telegraphy are now employed.

The Signal Corps of the army is at present operating a system of 3,000 miles of land line and 2,000 miles of cable in the Philippine Islands, 1,540 miles of land line which have been constructed in the past two years in face of the tremendous climatic and topographical dif-

ficulties of Alaska, 600 miles of cable which connects the Alaska system with the United States, and opened on the 17th of August of this year a wireless station across Norton Sound, which connects St. Michael with Cape Nome. The Signal Corps has developed a wireless system of its own. Beginning in 1900, it had in operation the first successful system in the United States, and has succeeded in working the distance between St. Michael and Cape Nome, 110 miles, after several failures of the commercial companies.

In the American armies, both of the North and the South, in the war of 1861 to 1865, was the first application of the telegraph under war conditions. The advantages and results proved so satisfactory that nearly all of the foreign powers have followed our methods, and the present modern system of field communication is but an amplification of the results obtained in that war, taking advantage of the engineering progress and the recent developments in the arts of telegraphy, telephony and cable working.

The telephones used in fortress service are modifications in design alone of the standard commercial types. Portability, simplicity, and mechanical strength are the essential features covering the design of all field telegraph and telephone apparatus.

While great progress has recently been made in the application of wireless telegraphy for the exchange of messages over water, its value for land communication, except in very exceptional cases, is quite problematical. The distances which as yet have been covered in land working are of comparatively short length, and its certainty of operation without interference is as yet unproved. The existing methods of communication have proved sufficient, especially as a field line, under ordinary circumstances, may be erected at the rate of from one to three miles an hour, depending upon the character of the ground. Whenever absolute syntonic working is achieved and interference by the enemy can be prevented, wireless telegraphy may have a valuable

field on land in the future, but, at the present outlook, it is much more suited to the operations afloat than ashore.

Before the outbreak of the war with Spain the cable operations of the Signal Corps were confined to maintaining the limited systems of cable communication between the various forts in the harbors of this country. When the expedition arrived off the coast of Cuba, near Santiago, the French cable leading to that point was cut, and, to avoid delicate questions of neutrality, the first war cable ever laid by our government was run from Guantanamo to Siboney by the Signal Corps and connected with the military line to Shafter's headquarters, so that the White House was only twenty minutes in time away from the firing line in an enemy's country.

As soon as the Philippine Islands were occupied, inter-island communication became so essential that the Signal Corps was called upon to take up the question of deep-sea cable engineering. Apart from its value as a means of communication, the establishment of the Philippine cable system gave the American manufacturers an opportunity to engage in the production of deep-sea cable, and has resulted in the establishment of such plants as will in future enable us to obtain at home this most important war material, and not place the government at the mercy of foreign producers, whose friendly interest cannot always be counted upon.

In the earlier emplacements and batteries designed for sea-coast defense no provision was made for using electricity, not because the desirability of its use was not considered or understood, but from a desire to mount as many guns at various localities as possible, using the very limited appropriations received from year to year for this purpose rather than for purposes not absolutely necessary. As the works for defense advanced, small available balances were expended for lighting batteries already completed or nearly so. Where the emplacements offered available room, such plants were installed in the battery; when such was not the case, small power-houses were constructed near the batteries for the purpose, and in some cases two or more batteries

were lighted from the same plant, but this was rather unusual. Such plants were necessarily small, operated in some cases by steam power, when the smokestack or steam escapement could give no possible clue to an enemy, but in the majority of cases they were operated by a gas engine. The lamps ranged in voltage from 80 to 100; generators, switchboards, etc., were arranged to suit the particular conditions at the battery under consideration and the money available. These plants were provided with a small storage battery as a reserve, to obviate the necessity of operating the entire plant every time the lights were desired, and in their entirety were so simple that an intelligent enlisted man was able to operate them.

The number of such plants installed was comparatively small, and the subject had been regarded as rather in an experimental stage, but sufficient experience had been had to warrant a serious consideration of the subject, with a view to applying electricity in all gun batteries for furnishing light and also for supplying power to raise the projectiles of the larger calibred guns from the level of the magazines or shot rooms to the gun platforms. Thus far, it must be understood, the emplacement lighting and the power for operating the ammunition hoists were alone considered, so that the conditions that such installations were designed to meet were: Intermittent service, inexpert and non-continuous attendance, and exposure of the generator and switchboard apparatus to the moisture of the emplacements, since complete protection against all kinds of fire from a hostile fleet was advisable.

While centralization was considered desirable, it was not to be carried beyond the limits within which the standard voltages of all parts of the system could be maintained with a reasonable expenditure of copper, so at some posts where the batteries were considerable distances apart there might be two or more plants. The power-houses were to be in one of the batteries, if room were available, or in a bomb-proof structure built for the purpose and to be divided: For steam

plants, into rooms for boilers, for engines and generators, and for accumulators; for oil engines, into rooms for engine and dynamo, for cooling tanks, if required, and for accumulators. The oil engine has given considerable trouble where used, because the engine did not accommodate itself quickly to fluctuations in the load, and on account of the impossibility of securing men in the immediate vicinity competent to take care of the engine and to make repairs in case of an accident or injury. Consequently the steam plant was advocated.

The considerations governing the problem are as follows:

1. The greatest probability that the plant would be ready for service at any future time, having in view simplicity of design and freedom from deterioration.

2. Uniformity of methods of operation and of methods of construction, so far as the latter involved the former.

3. Economy of operation.

4. Economy of first cost.

5. High commercial efficiency.

A vertical boiler and a generating set, consisting of a vertical high-speed engine direct-connected to a direct current, compound-wound, multipolar dynamo, the engine and dynamo resting on a common bed-plate, are adopted for all future installations. Reserves in the form of accumulators were installed in all batteries of 6-inch calibre guns or greater, their capacity to be determined by the lighting load only, without reference to the power load represented by motor-driven machinery, as the hand-operating devices are in themselves a satisfactory reserve. Reserves for the batteries to the smaller guns are made portable. The reserves are distributed so that a single accident or injury will not disable both the generator and the reserves at the same time, and also in order that any injury to outside wiring leads to the central generating plant could not disable the reserves. Under these conditions the reserves are distributed among the various batteries, the reserve

for each battery being sufficient in capacity for the lighting load of the particular battery with which it was connected.

While uniformity is considered desirable in all parts of the installation, it is the general opinion that the identical arrangement and operation of all switchboards is so very desirable that it will be insisted upon in all future constructions. The chief requirements are a dry and clean situation, high insulation and protective appliances, and the reduction of the number of manipulations required to the lowest possible limit.

Overhead wires are advocated wherever they can be obscured from the enemy's view, and for this purpose ordinary weather-proof wire with high-grade insulators on stout poles is the practice. If the conditions of the ground are such that an aerial line cannot be concealed from view, the cables are placed underground, carried in well-laid vitrified conduit at a depth sufficient to give ample cover.

The importance of the searchlight up to 1901 had not been fully appreciated, and though they were provided at the various defenses for the purpose of guarding the mine fields against a night attack, their use in connection with the batteries had received but little consideration. As a result of maneuvers, the necessity of searchlights as an adjunct of defense was established and another factor was introduced. Future plants would have to furnish sufficient power not only for emplacement work, but also for searchlights, and this addition required an increase in the capacity of the machines to meet the greater demand.

Thus far the plants installed were used for emplacement work only, the storage batteries were charged and discharged at stated intervals and, as noted above, the service was intermittent. The plants were in the hands of the Artillery Corps, and the officers desired to avail themselves of these plants for lighting their quarters and posts, thereby insuring, by their constant use, better care. As a result the War Deparement authorized the use of such plants, if of sufficient size to do this

work, by the Quartermaster's Department when authorized by the Chief of Engineers, "provided that the needs of defense shall have precedence over post lighting or power supply in any case in which both uses are simultaneously desired." It was further ordered that in future, when funds permitted, the Engineer Department should construct such ducts, service wires, etc., as might be necessary to deliver current to the buildings and to the exterior lights. The Quartermaster's Department was to wire the buildings, furnish the exterior lamps and to supply all plants used for post lighting with the necessary materials and funds for their repair and preservation. A third service was thereby imposed.

The Quartermaster's Department and the Artillery Corps desired for such lighting of posts low potential service throughout, mainly on the ground of simplicity and because of the character of labor that was to be employed in operating the plant; a centrally-located plant, due consideration being had to protection against hostile fire, accessibility for supplies, etc.; that the plant be sufficiently large for doing all the work connected with the fortifications, and alternately for post and building lighting (in other words, the larger of these two services would govern the size, assuming direct-current machines to be used); that the generator unit be subdivided, thereby providing two engines and generators, so that in case of injury to either half the other would be available for the more necessary purposes; and, finally, that all wires be underground rather than overhead, in order to reduce the cost of maintenance. With these additional services the original conditions were changed.

The fullest possible electrical demand at any military post will embrace, therefore:

1. Searchlight service.
2. Emplacement service.
3. Garrison service.

And the engineer officer must design his plant for these three services.

The searchlight service requires current for a number of searchlights to be used in conjunction with the bat-

teries placed in their vicinity. The number and size of these lights for any particular post is definitely known in advance.

The fortification service requires current for lights in the various rooms of each emplacement, on each gun-platform, in the range-finding stations; current for power to work the motors for ammunition service, for transferring, elevating and depressing the guns and to operate a machine shop for minor repairs to the guns and carriages, and, finally, current for the recently adopted telautograph system connecting the range-finding stations with each other and with their respective batteries.

The garrison service requires current for lighting the grounds and buildings, including barracks, quarters, hospitals, store houses, etc., which may be in close proximity to the batteries or at considerable distance from them, depending on the size and configuration of the reservation.

In general, the use of aerial mains and branches for garrison lighting, in conformity with the prevailing practice of low potential current distribution in all but the largest cities, is regarded as feasible in cases where underground mains would be unduly expensive.

A system of submarine mines usually involves stationary torpedoes planted under water, anchors for holding them in position, cables for connecting them electrically with the shore, and operating apparatus in a sheltered position on shore.

By far the greater part of all submarine mines are electrically operated from the shore. This follows directly from a consideration of the conditions to be met in devising a system of mines. It is very desirable for a mine to explode automatically when struck by a hostile vessel; but it is equally desirable for it not to explode if it is struck by a friendly vessel; the defense should also be able to explode the mines at will from the shore, in case a hostile vessel comes near; but seems likely to miss them. All these things are rendered possible by mines electrically operated from the shore.

Coming now to the electrical arrangements, if firing were by judgment alone, nothing would be needed but a circuit from the firing battery through the detonators in the torpedo to earth, with a firing key in the casemate. Even very defective insulation would not interfere with the workings of the system, if the battery was enduring and sufficiently powerful. It would interfere with the daily tests, however, because of the variations in resistance which would occur even if no leaks or other defects developed in the torpedo itself. If firing is by contact alone, the necessary arrangements are a little more complex.

In order to admit of daily electrical tests—which must include the circuit through the detonators to be of any value—there must be a continuous circuit through the torpedo; it must be of high resistance; so that even if the firing battery is on, it cannot fire the mine. There must be a circuit-closer in series with the detonators, and in parallel with the high resistance. When the mine is struck, the circuit-closer acts, and opens up a circuit of lower resistance through the detonators. It is assumed that the detonators are of the type having a continuous bridge of fine wire, surrounded by some fulminating substance, and designed for a relatively large current under moderate e. m. f. This is the most certain and reliable form, and is always easy to obtain. If the firing battery is on, the torpedo should explode when the circuit-closer acts.

It is desirable, however, to know whether a torpedo is struck, or whether its circuit-closer acts from any other cause, even if the mine is not to be fired. Moreover, it is objectionable to keep the cables under such high voltage as is necessary in a firing battery. It therefore becomes desirable to have another battery of very constant e. m. f. always on the circuit. Its e. m. f. and all the resistances in circuit should be so proportioned that normally a tiny current is always flowing; but when a circuit-closer acts, this current should increase to such a point that it will drop a signal, showing to which triple group the torpedo belongs, and also close the circuit of the firing battery through the cor-

responding cable core. In case the torpedo is fired, the explosion may cause the circuit-closers of neighboring mines to act, and thus the whole system might go up, seriatim. To prevent this, some device is needed which will allow the firing current to flow long enough to explode certainly the mine that is struck, but which will break it immediately thereafter, and keep it broken long enough for neighboring mines to right themselves. It should be remarked here that if ground mines are used for automatic firing, the circuit-closer must be carried in a buoy, similar in form to a buoyant torpedo, anchored to the ground mine, and having an electrical connection with it; so that, with ground mines, the requirements are the same as with buoyant mines.

It will readily be seen that to accomplish all the above objects a more or less complicated set of apparatus is required. It is a good plan so to arrange the signal drops that when they fall they will close a bell circuit, thus causing a bell to ring continuously until the signal is raised; it is also well for the device which cuts off the firing battery after an explosion to ring a bell as long as the firing circuit is open; this gives reasonable assurance that a mine has exploded, even if in the noise of a battle the explosion itself is not heard; pilot lights would do as well as a bell. It is also well to have a very feeble battery for testing purposes only; thus it will be already seen that there may be as many as five separate circuits to provide for in the operating casemate. In addition there may be one more; if a torpedo is struck and fired, the end of the cable leading to it will form an earth which, if not cut out, might be sufficiently good to keep throwing the firing battery on; it would so alter the resistances as to interfere seriously with the proper working of the system, at any rate. At the triple junction-box, a fuse could be inserted, able to carry the firing current, but susceptible of being blown by a more powerful one to be applied as soon as the other mines of the group have righted themselves. If now we assume that a small engine and dynamo are

used in connection with storage batteries to supply current to the various circuits, it will readily be seen that the switchboard problem in the casemate is not a simple one.

If, in addition to automatic firing, it is desired to use judgment firing, it should be possible to switch out the high resistance in the mine, or else have this resistance in the form of the primary of an induction coil, with additional detonators in its secondary circuit; in this case, an intermittent or alternating current of high potential and small volume flowing in the primary would induce a firing current in the secondary. A whole triple group would then be fired, and the corresponding core of the multiple cable would be detached from the operating apparatus altogether, until such time as the mines could be replaced.

In purely automatic firing, the high resistance might be omitted altogether, but then a break in the cable core would give the same indication as a mine in normal condition; and the torpedo itself might be filled witn water and sunk to the bottom without the fact being discovered.

The daily tests consist in measuring the resistances of the various circuits and testing all movable parts in the operating casemate. Damage to the system always affects these tests, and the expert electrician in charge must learn to infer from his tests what is the probable nature of the damage.

It will readily be seen that except for purely judgment firing, the insulation resistance of cables and joints must be very high, and must remain so. Details of apparatus actually in use have been omitted, because they are classed as confidential; but enough has been said to show to an electrical engineer that submarine mining presents some problems that demand serious attention. Not the least of these is the problem of junction-boxes which will allow of rapid jointing work of a quality sufficiently good to withstand submersion in sea water for months at a time. Another serious problem is the cable itself. It takes time to make it. If it is kept in store, either wet or dry, the insulation becomes brittle

and when the cable is unwound from the reels, in laying, the insulation cracks. Hitherto the cable used for this purpose has been insulated, taped, and armored. While the work has been of a high grade, it seems to some of the best authorities the army must soon come to the use of cable having a lead covering outside of the insulation and steel wire armor outside of the lead. Then, as long as the lead is intact, cracks in the insulation will be of no consequence. But this form of cable again will be heavier, harder to handle, more difficult to splice, and considerably more expensive than the armored cable without the lead.

Even after the details of a system of mines are satisfactorily worked out, the planting is a very serious matter and always will be, unless we discover some way of controlling and firing the mines by induction, without electrical connections from the shore, thus eliminating the cable. Perhaps the development of wireless telegraphy may ultimately make this possible.

DOME OF THE CAPITOL.

ELECTRICITY IN THE NAVY.

THE use of electricity aboard modern naval vessels is so extensive that to interrupt the supply during action would mean certain defeat for a vessel were she matched against any vessel which approached her equal.

The best manner in which to convey an adequate conception of the extended and important application of electricity aboard naval vessels is to give a general description of the equipment of a modern battleship.

The Connecticut and Louisiana, the two 16,000-ton battleships now under construction, the former at the New York Navy Yard, the latter at the works of the Newport News Shipbuilding and Dry Dock Company, represent the latest type of battleship, greater in displacement than any heretofore designed for our navy and carrying heavier armament than any warship now afloat, either in our navy or abroad.

The main battery consists of four 12-inch, eight 8-inch, and twelve 7-inch breech-loading rifles. The 12-inch guns are mounted two each in a forward and after turret, the 8-inch guns two in each of four turrets arranged one at each corner of a rectangle, or what is commonly known as quadralateral turrets, the 7-inch guns are each in a separate armored compartment on the gun deck. The secondary battery consists of twenty 3-inch (14-pounder) rapid-fire guns, twelve 3-pounder, seven automatics, and numerous guns of smaller calibre.

These battleships have been designed to carry two complete and independent electric plants each capable of handling the entire load which may be required in action.

The electric applications aboard ship are divided into three distinct classes: (1) Illumination, (2) power for driving auxiliaries, (3) signalling or communication.

The lighting system is installed as two distinct systems, each having separate feeders and mains and known

as the "Battle Service" and "Lighting Service." The battle service comprises all lights below the protective deck, including those in engine and fire rooms, magazines, store rooms, and the like; all lights at guns, ammunition hoists, winches, cranes and other auxiliaries whose operation may be required during action; signalling lights, the ship's running lights, and only sufficient other lights in passages to afford convenient access to the various portions of the ship. When necessary to install a light in a location which might render it visible by the enemy, a "battle lantern" is used, this lantern being fitted with a sliding screen which allows the light to shine only over an arc of about 90 degrees, and can be entirely screened if required, this feature being identical with that of the ordinary bull's-eye or dark lantern.

The battle service will efficiently light all parts of the ship subject to access during action, and all other auxiliaries whose manipulation and operation during action is essential, but at the same time to shield all lights against external visibility.

The lighting service includes all lights not included in the battle service, such as lights in state rooms, offices, mess rooms, crews' spaces, and the like, and also supplies current to the desk and bracket fans in officers' quarters. To efficiently light each of these vessels requires the use of eleven hundred fixtures, of which about 730 are on the battle service, the remainder being on the lighting service.

The fixtures used are simple in design and neat in appearance, the types most used being the steam tight globe and the ceiling fixture. These consist of a casting which has a boss into which the conduit carrying the wires taps, and a knuckle thread into which the glass globe screws, the lamp socket being secured to the casting by machine screws, a rubber gasket intervening. The steam-tight globe is protected by a stout metal guard, as shown in the illustration. This type of fixture is made in three types, differing only in the method of support; that shown in Fig. 1 is the bulkhead type and is secured by a bracket cast in one with the conical-cap, the other types being the drop type, which is supported by the con-

duit alone, and the deck type, in which the conduit enters the fixture from the side instead of the top, the fixture being supported by a bracket cast across the top of the conical cap.

The ceiling fixture is used in passages around the officers' quarters, in reception cabins, mess rooms, and the like, and is the standard overhead light for all locations, in which the fixture is not liable to injury. The steam-tight globe is used in engine and fire rooms, ammunition passages, store rooms, and is the standard fixed light for all locations where the fixture is subject to injury.

Six hand-control projectors, or search-lights, will be installed. These will be located, one on a platform at the base of the fore topmast, two on the flying bridge, one on a platform at the base of the main topmast, and two on a platform on the mainmast well above the after bridges. Each projector will be equipped with a horizontal lamp designed for both hand and automatic feed. Each light will operate on a 125-volt circuit in series with a regulating rheostat, with 60 volts across the arc.

Motors will be used for the following purposes: (*a*) To drive ventilating fans and blowers, (*b*) carrying ammunition from magazines to hoists, (*c*) hoisting ammunition, (*d*) turning turrets, (*e*) elevating and depressing gun, (*f*) ramming shells into the breech of guns, (*g*) to operate deck winches, (*h*) to operate boat cranes, (*j*) to whip ammunition from the main deck to the bridge and military tops, (*k*) for laundry machinery, (*l*) for driving tools and in machine shop, (*m*) for operating automatic power doors, (*n*) for operating fresh water pumps and sanitary pumps, (*o*) for driving air compressors for charging torpedoes.

The ventilating system comprises thirty-three fixed fans, varying in size from those requiring a fraction of a horse-power each for their operation to 80-inch steel plate fans requiring 11 horse-power each. Each of the above fans will be driven by its own independent shunt-wound electric motor, direct-connected, the control panel containing the usual starting resistance fitted with automatic overload and no voltage release. All fans are designed to deliver their specified amount of air at a

pressure of 1 ounce when running at normal speed, but are capable of being driven at about double normal speed, in which case the air is delivered at a pressure of 1½ ounce. The speed control is effected by varying the resistance except for the smaller fans, in which case resistance in series with the armature will control the speed.

In addition to the above, each ship will be supplied with six small portable electric fans, each consisting of a ¼ horse-power series motor mounted on a common shaft with an exhauster which it drives at a speed of about 2,200 revolutions per minute, causing a delivery of about 500 cubic feet of air per minute (free exhaust). These sets are very compact, the overall dimensions being about 18x18x12, and weigh approximately 100 pounds. They are used for temporary ventilation when necessary to work in such localities as are not reached by the main ventilating system, such as double bottoms, inside of boilers and the like. Each of these sets is supplied with two 25-foot lengths of canvas hose with couplings permitting of attachment to inlet and outlet of exhauster or to attach together, forming a 50-foot length, which can be connected to either the inlet or the outlet of the exhauster.

The officers' quarters, wardrooms and the like are liberally fitted with desk and bracket fans, the former being 12 inches in diameter, rated at 1-12 horse-power, the latter 16 inches in diameter rated at 1-6 horse-power. Forty-five of the former and eight of the latter will be installed on each vessel.

At a comparatively recent date a ship's ventilating system consisted of a few large-sized blowers, generally located in pairs with large main ducts having many turns, bends and with branches leading to the various compartments. This system required an excess in air pressure at the fan in order to maintain a certain head at the discharge outlet, owing to the loss by friction of the pipes and to the indirect leads of the main ducts. Many of the principal water-tight bulkheads were pierced by the ducts and this necessitated the use of valves so installed as to be of convenient operation,

which could be closed in an emergency to maintain the water-tightness of the various compartments below the water line. All leads through the protective deck required armored bars or gratings in the openings.

The ventilating systems of the Connecticut and Louisiana are so designed as to minimize the number of leads through the protective deck, and in no instance is any one of the principal water-tight bulkheads pierced by a ventilating duct. The flexibility of this system employing a number of small units as compared with a few large ones, possesses many advantages which are at once apparent, and the installation of such a system is only rendered possible by the use of the electric drive.

Conveyor motors are used for carrying ammunition from the magazines, along the passages to the base of the ammunition hoists. Four conveyors will be installed, two leading aft from the forward magazines, one on the port side and one on the starboard side, and two leading forward from the after magazines, one port and one starboard. Each conveyor will be about 80 feet long and will consist of two endless sprocket chains with metal aprons and stiffeners at suitable intervals. Motors, one to each conveyor, will be shunt wound, reversible, of about 5 horse-power, and will drive through gearing.

Twenty-six endless chain ammunition hoists, each driven by a 3 horse-power motor, will deliver the ammunition from the lower passage to the 7-inch guns and secondary battery. These are in addition to the ammunition hoists for the turret guns. All the main battery guns will be supplied by hoists leading direct from the lower passages, but certain guns of the secondary battery are so located as to require the ammunition being hoisted first to the berth deck, then carried along to other hoists and raised to the upper deck at the gun locations.

The new arrangement of the main broadside battery, wherein by means of a center line armor bulkhead on the gun deck and suitably located transverse armored bulkheads, each of the twelve 7-inch guns is located in a separate armored compartment, renders imperative a separate ammunition supply for each gun. On former

vessels the main broadside battery was installed in a more or less open compartment, which would render possible the supplying of ammunition to more than one gun from the same hoist. The new arrangement in which a gun would be temporarily rendered *hors de combat* by a failure of its individual ammunition hoist adds to the importance of this electrical application and the reliance which must be placed in the electric motor and in the ability of the ship's plant to furnish the necessary power under any and all conditions.

Each ammuniton hoist motor will be shunt wound, reversible, enclosed, dust and moisture tight, with suitable openings (fitted with water-tight covers) to allow inspection and adjustment to brush rigging and the like. Motors will be geared to the ammunition hoist sprockets, each armature shaft being fitted with a solenoid brake, which will set automatically and prevent turning of the armature in case of failure of the line voltage.

Each of the six turrets with its respective pair of guns will be equipped for electrical rotation. This will be done by fitting each turret with two motors of equal capacity, either one of which will be capable of operating the turret in case of failure on the part of the other, although normally they will both operate in parallel. For the 12-inch turrets two motors of not less than 25 horse-power will be installed in each, and for the 8-inch turrets, two motors of not less than 15 horse-power will be installed in each. The Ward Leonard system of control will be used.

A motor-generator, designed for comparatively high speed and consequently compact and not over-heavy, will be installed in the barbette of each turret. The motor end will be connected direct to the main power bus-bars of the main switchboard.

The generator terminals are led direct to the turning motor terminals, the field of the generator end of the motor generator being led through a variable resistance, the latter being controlled by the turret operator. It will be readily seen that the motor, having a separately excited field, will run at a speed proportional to the impressed armature voltage, the latter being dependent on

the field current of the generating set, which is controlled by the turret operator; and furthermore, the motor speed will be definite for any fixed position of the controller handle, and that speed will be maintained against any and all variations of load, due to friction, listing of the ship, the impact of a shell, up to the point where a fuse blows or a circuit-breaker is thrown.

Each turret gun is mounted on trunnions and elevated or depressed to the proper angle by means of an electric motor. As the guns are balanced on the trunnions, the elevating or gun training motors merely have to overcome the friction load; or in case a shell is inserted in the breech of the gun prior to the elevation of the gun to the proper angle, the training motor is subjected to a load in excess of the friction load in depressing the muzzle, and a load smaller than the friction load if elevating the muzzle. Each 12-inch gun will be equipped with a 5 horse-power gun-elevating motor, and each 8-inch gun with a 2.5 horse-power gun-elevating motor. These motors will be shunt wound, reversible, enclosed, waterproof, with the usual hand holes for inspection. Rheostatic control will be used.

For ramming the shells into the breech of the 12-inch and 8-inch guns, a "rammer motor" is installed, one for each gun. These motors are series wound and subject to loads which are largely in one direction. They operate the rammer through a friction drive so adjusted that in case the shell is set home before the motor is stopped, the clutch will slip before the motor draws sufficient current to throw the circuit-breaker. Each 12-inch gun will be equipped with a 7 horse-power rammer motor and each 8-inch gun with a 5 horse-power rammer motor.

Each turret gun has its individual ammuniton hoist, which works on the principle of cables or hoisting ropes winding on and off a drum which is actuated by an electric motor. The motors will be operated through a controller with a single handle which will allow sudden reversal; the carrying of the load in either direction; the automatic locking of the drum against rotation in either direction, when the current supply is cut off, and the operation of the motor when under any load on each of

five speeds. For the 12-inch guns the motors must handle a load of about 3,200 pounds, and will be of about 30 horse-power each. For the 8-inch guns the motors must handle a load of about 1,000 pounds, and will be about 8 horse-power each.

Each ship will be fitted with six double-headed winches, two forward on the main deck, two on the upper deck in the waist of the ship, and two well aft on the quarter deck. These winches will be used in coaling ship, handling anchors and in stowing cargo. Each winch will be operated by a 25 horse-power motor. These motors will be series wound, reversible, enclosed, water-tight, and designed to withstand strains due to increase of speed on sudden removal of the load. The two forward main deck winches must each be capable of hoisting a 2,200-pound load at a speed of 300 feet per minute, and the same load at a speed of 30 feet per minute; the two upper deck winches to hoist 2,200 pounds load at a speed of 300 feet per minute, the quarter deck winches to hoist a 2,200-pound load at 300 feet per minute, and a 13,200-pound load at 50 feet per minute. Specifications allow an option between gearing and electric devices for obtaining the necessary speed variations.

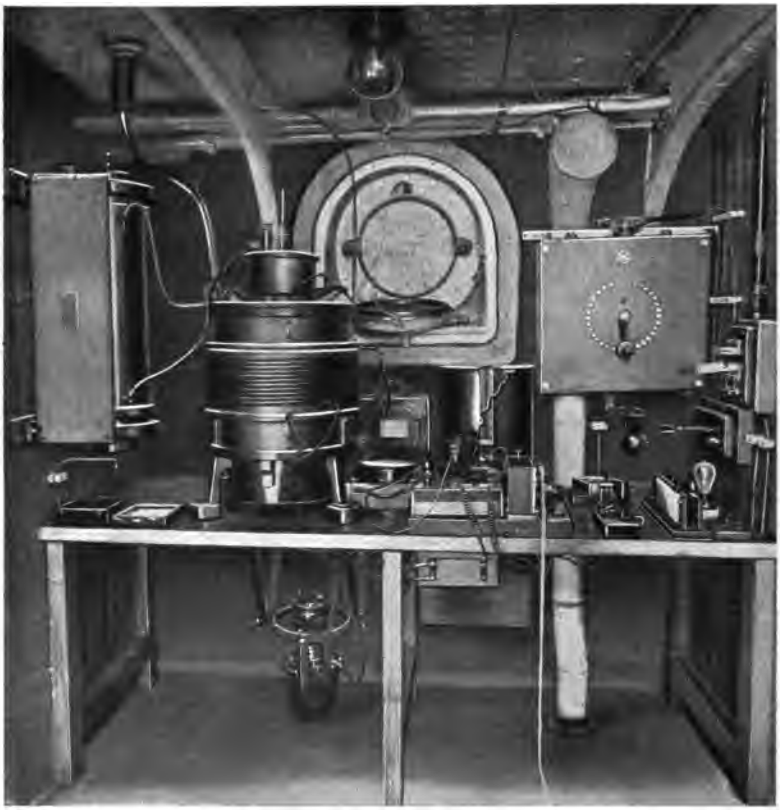
Two boat cranes will be used to handle the ship's boats and launches, of which each ship carries a sufficient number to float her entire complement of over 800 men. The cranes will be electrically operated with separate motors for hoisting and for rotating. Crane requirements specify a hoist of 33,000 pounds at a speed of 25 feet per minute, and a rotation at the rate of one revolution per minute, while carrying the above load and with the ship heeled to 10 degrees. Motors will be enclosed, water-tight and reversible, the hoisting motor being series wound. Hoisting motors will be about 50 horse-power each, and rotating motors about 30 horse-power each. Both motors will be located on a platform which revolves with the crane. The revolution embracing a complete rotation, it will be necessary to lead the electric wires to the crane motors through contact

rings and brushes; the former will probably be on the rotating crane, the latter being the terminals of the feeder.

Laundry machinery will be electrically driven by an enclosed motor of about 10 horse-power. The machinery workshop of each vessel will include a 48-inch extension gap lathe, a 14-inch lathe, a 15-inch stroke column shaper, a vertical drill press, a 16-inch sensitive drill, a universal milling machine, a combined hand punch and shears, an emery grinder with two 12-inch wheels, and a 30-inch grindstone. All the machine tools will be electrically driven, either direct-connected or through shafting, and will require from 10 to 15 horse-power.

All doors leading between boiler rooms, between engine rooms, between boiler and engine rooms, from boiler rooms into bunkers, at the ends of the main ammunition passages and the like, and the main hatches through the protective deck, both fore and aft—in all forty-two doors and five armor hatches—will be worked on a power system. Each such door or hatch will be capable of operation on the spot by hand or by power, from either side of the bulkhead or deck, and all must be capable of being closed by power simultaneously from an emergency station, which will probably be located in the pilot house. If electrically operated doors are used, a 1 horse-power motor will be installed at each door and hatch, forty-seven in all. If pneumatic power is used, a motor-driven air compressor will supply the energy. In the latter case the motor will be automatically stopped and started by pneumatic operation of the controller. An indicator at the emergency station will enable the operator to determine whether any door or hatch is open or closed.

Two 2 horse-power motors, driving centrifugal pumps, will be used in connection with the fresh water system for circulation between the distiller and the various tanks. Motors will be automatically stopped and started by means of floats operating the controllers. Two 6 horse-power motors, driving centrifugal pumps, will be used in connection with the salt water sanitary service or flushing.



Operating Room, Wireless Telegraph
Fig. 1.

A wireless telegraph outfit will be supplied of the latest and most approved type. A typical operating room is shown in Fig. 1, the arrangement of apparatus being perhaps somewhat more compact than would be followed in shore installations; but, as all space on a battleship is at a premium, a more liberal assignment of room for this equipment cannot be made. The "aerial" can be seen coming through deck overhead through a heavy ebonite insulator. The "ground" is obtained by connecting direct to the hull of the ship.

An extensive application of electrical apparatus will be found in the systems of communication aboard these vessels. About ninety voice pipes will be installed, most of which will be fitted with suitable electric calling devices in the shape of push buttons, bells, buzzers and annunciators.

A liberal disposition of push buttons in the officers' quarters allow the calling of the various pantries, orderlies, messengers and the like, to the various state rooms, cabins, officers and mess rooms as required. A telephone system comprising some twenty-five lines, running to a central station, will be installed. In addition several private lines are installed, such as between navigator's stateroom and dynamo rooms, between chief engineer's state room and engine room, between surgeon's state room and dispensary, and the like.

In the various living spaces of each ship, single-stroke electrically-operated gongs, 12 inches in diameter, are installed. These gongs can be operated all simultaneously, from either the captain's state room, pilot house, conning tower, or executive officer's state room. The circuit closers are automatic in operation and ring the gongs continuously for thirty seconds when set in motion. These signals, known as general alarm gongs, are used for calling the men to quarters.

Located in spaces below the protective deck and at the main hatches leading below this deck, warning signals, or water-tight door alarms, are installed. These consist of solenoids operating a plunger in such a manner as to force air through a whistle, which gives forth a shrill sound. These warning signals are all capable of being

operated either from the quarter deck or the pilot house. They are used to give the signal for closing all water-tight doors and hatches, which is done when danger from collision or other cause is imminent.

Thermostats are installed in all coal bunkers and magazines and all storerooms containing combustible material. They consist of a helical metal coil having a high temperature coefficient. This coil is mounted with one end free, in such a manner that the torsional effect produced by a slight rise in temperature causes a slight displacement of the free end. This closes an electric circuit, which leads to a drop on an annunciator located under the eye of the captain's orderly. These thermostats are enclosed in a heavy composition case and are sufficiently strong to allow their installation in any portion of a coal bunker. It is customary to install them well down in the bunkers at about the depth which experience dictates is most subject to spontaneous combustion. Coal bunker and store room thermostats are set for 200 degrees F., and magazine thermostats for about 100 degrees F. A total of 171 thermostats will be installed on each vessel, of which about 70 will be in coal bunkers and 67 in store rooms, each group being on a separate annunciator.

Electric revolution indicators will be installed in the pilot house and conning tower for signalling the number of revolutions of each main engine shaft. These indicators will be of the "tick-tack" type, each revolution of the shaft closing the circuit through an electric magnet on the indicators, which in turn draws down its armature and causes a pointer to vibrate through an angle of about 30 degrees. Each indicator has a pointer and magnet for "ahead" and "astern," corresponding to "forward" and "reverse" rotation of the engines.

Electric engine telegraphs located in the pilot house and in the conning tower, with indicators in each engine

room, will permit slight variations in speed to be signalled. These instruments are of the "lamp" type, and consist of 5 candle-power electric lamps arranged in separate compartments, over the face of which are brass templets with the desired order cut through. By illuminating the lamp in any compartment, which is done by closing the circuit at the transmitter, the light shines through the letters or figures on the dial or the brass templet and indicates the desired order.

Helm order telegraphs located in the pilot house and conning tower, with indicators at all steering stations, will permit of electrically signalling to the helmsman the desired helm angle. These instruments are similar in construction to the engine telegraphs, except that the markings and the number of indications are different.

Electric rudder indicators of the lamp type, located at all steering stations and connected to a transmitter on the rudder head, will indicate the angle at which the rudder is set, and acts as a check in determining if an order transmitted to the helmsman by the helm order telegraph has been carried out.

For each turret ammunition hoist an indicator will be installed which will show the operator in the turret when the ammunition car is loaded and ready for hoisting, and also during the lowering of the car, when it is approaching the lower limit of travel. These indications will consist of lamps in view of the turret operator, which are automatically lighted and extinguished by contacts operated by the passage of the ammuniton car.

The top of each mast will be fitted with a double truck light, which consists of two 32 candle-power lamps mounted one in a red and the other in a white lens. Both truck lights will be controlled by one "double-truck light controller" located on the forward bridge. This controller permits the illumination of either light on either truck, which light can be pulsated by means of a pulsator on the side of a controller. These lights are

used to signal when cruising in squadron formation. A white light signals "steaming ahead," a pulsating of white light "slowing down;" a red light, "engines stopped;" a red light pulsating, "going astern."

Each ship will carry two night signalling sets. These sets consist of four double lanterns suspended on a ladder from an outrigger near the truck of each mast. Each lantern consists of two 32 candle-power lamps mounted in pressed glass Fresnel lenses, one lamp of each double lantern being mounted in a red lens, the others in a white lens. The lanterns will be spaced 12 feet apart. By means of a suitable keyboard on the bridge, the red or the white light in any or all lanterns or any combination of red and white lights on the four lanterns (only one light on each lantern) can be illuminated. By means of a pre-arranged code of signals, messages can be transmitted to any station within range of visibility of the lights. The use of two night signalling sets, one suspended from the foremast swinging outboard to port, the other from the mainmast swinging outboard to starboard, permits signalling to any station regardless of its bearing to the ship's head; whereas with only one night signalling set the relative location of the ship and the station to which it is desirous of signalling might be such that the mast from which the lanterns are suspended would intercept the path of the light and render the signal indiscernible. The keyboard is mounted on a pedestal and is enclosed in a case with a hinged cover. The apparatus is similar in appearance to a typewriter keyboard, and the depression of a single key displays the desired combination of lights. A cable of 16 conductors running to the lanterns enters the keyboard through a detachable water-tight coupling.

A summation of the electric auxiliaries on each ship with the probable maximum current required by each group, both for "in action" and for "cruising efficiency" is given in the following table. In estimating current required for the various motors, efficiencies varying from 80 per cent. up have been assumed, depending on the size of the motor:

Name of Appliance.	Horse-power.	Number in installation.	Number used in action.	Used for cruising.	Amperes: total installation.	Amperes: total used in action.	Amperes: probable used in action.	Ratio: probable to total in action.
Incandescent fixtures	....	1100	800	700	550	400	270	2/3
Arc lamps	....	10	10	10	35	35	35	1
30-inch search lights	....	6	6	2	450	450	300	2/3
Fans, 1-12-H. P.	....	45	......	45	23	......	......	......
Fans, 1 6-H. P.	....	8	......	8	8	......	......	......
Port. vent. sets 1/4-H. P.	....	6	......	6	18	......	......	......
Interior communications	....	......	......	......	?	......	25	......
Total	....	......	......	......	......	885	630	......
Main vent. blowers	3/4 to 10	33	33	33	950	950	630	2/3
Ammunition carriers	4	4	4	......	120	120	150	1
Ammunition hoists, chain	3	26	26	......	570	570	285	1/2
Ammunition, turrets, 12″ guns	30	4	4	......	800	800	535	2/3
Ammunition, turrets, 8″ guns	8	8	8	......	450	450	300	2/3
Gun elevating motors, 12″ guns	5	4	4	......	140	140	70	1/2
Gun elevating motors, 8″ guns	2 1/2	8	8	......	160	160	80	1/2
Gun rammer motors, 12″ guns	7	4	4	......	200	200	*	......
Gun rammer motors, 8″ guns	5	8	8	......	280	280	*	......
Turret turning motors, 12″ guns	25	4	4	......	670	335	170	1/2
Turret turning motors, 8″ guns	15	8	8	......	840	420	210	1/2
Smoke blowers	1/2	12	12	......	50	50	25	1/2
Deck winches	25	6	......	6	1000	......	......	......
Boat cranes, hoisting	50	2	......	2	660	......	......	......
Boat cranes, rotating	30	2	......	2	400	......	......	......
Whip hoists	3	6	6	......	130	130	65	1/2
Laundry motor	10	1	......	1	70	......	......	......
Machine shop motor	10	1	......	1	70	......	......	......
Powder door and hatches	1	47	47	......	350	350	120	1/3
Fresh water pumps	2	2	......	2	30	......	......	......
Sanitary pumps	6	2	......	2	80	......	......	......
Air compressors	70	2	2	......	840	840	840	1
Total	....	194	178	49	9969	5193	3450	......

* Rammer motors not operative during hoisting of ammunition.

The entire electric equipment of each ship aggregates 9,969 amperes, which, at the standard voltage of 125, corresponds to 1,250 kilowatts; and the total power required by auxiliaries which are operative in action, corresponds to 885 amperes, or 110.6 kilowatts for the lighting and projector load, and 5,795 amperes, or 724 kilowatts for the power load, making a grand total of 834.6.

As many of the battle auxiliaries are of such a nature as to be subject to intermittent service, the probable maximum battle load is well below this figure, the estimated values being as indicated in the next to the last column, viz.: 630 amperes or 78.8 kilowatts for the lighting and projector load, and 3,450 amperes or 431 kilowatts for the power load, making a grand total of 510 kilowatts.

As previously stated, two independent power plants will be installed on each ship, and are designated as the forward dynamo room and the after dynamo room. Both will be located beneath the protective deck on a platform whose level comes between the upper platform and the lower platform, this special platform being necessary to secure sufficient headroom to install the generating sets. The forward dynamo room is located between the forward magazines and the boiler spaces, the after dynamo room between the boiler spaces and the main engine rooms.

Four 100-kilowatt, 125-volt generating sets will be installed in each dynamo room. These sets will be direct-connected, the engines being vertical cross compound, of the enclosed type and fitted with forced lubrication.

Each dynamo room is capable of handling independently the entire battle load. This arrangement was considered imperative in view of the extended application of the electric drive to the important battle auxiliaries and in view of the danger of the electric plant being rendered inoperative from the following causes:

(*a*) Dynamo room rendered uninhabitable by breaking of a steam pipe. (*b*) Dynamo room rendered uninhabitable by flooding of the compartment. (*c*) Generators or engines being damaged by heavy short circuits. (*d*) Damage to compartment by shell from the enemy.

Distribution of energy to all battle service when one dynamo room is out of commission and uninhabitable necessitates either duplicating the wiring to each auxiliary, viz.: one current leading from each dynamo room with a throw-over switch at each auxiliary; or wiring from distribution boards which are located external to and yet capable of electric connection to each dynamo

room at will. This latter scheme has been adopted, using two main distribution boards, one adjacent to each dynamo room, and in addition duplicate wiring has been specified for certain of the more important circuits.

Convenience dictates that the switchboards for control of the generators be located in the respective dynamo rooms, and that the distribution boards be located adjacent to the dynamo rooms. These distribution boards are, furthermore, each in its water-tight compartment, these compartments being each provided with a water-tight door leading direct into the adjacent dynamo room and with another door permitting access to the compartment independent of the dynamo rooms.

Provision is made for the supply of energy to the lighting system and the projectors from a separate generating set; the ordinary assignment in action with one dynamo room in use would be one generating set to the lighting system and the projectors and three generating sets in parallel on the power system. The arrangement of main switchboards will, however, permit the operation of any or all generators in either dynamo room in parallel on the entire ship's load. On ships so powered as to occasion the assignment of generating sets of 50-kilowatt capacity or less to the lighting system, it has been the custom to make provision for supplying the projectors from a generating set independent of the lighting system; but in the present instance any generating set is of ample capacity to handle the combined lighting and projector load. As the power required by each projector is less than 10 per cent. of the capacity of a generating set, several projectors could be thrown in circuit simultaneously without causing a material "dip" in the intensity of the incandescent illumination.

Two main switchboards and two distribution boards are used. Two sets of feeders, one for lighting and projectors, the other for power, are run from each main switchboard to each main distribution board. In general, the forward distribution board supplies all circuits forward of the amidship portion of the vessel, and the after distribution board all circuits abaft the amidships portion of the vessel.

Under normal conditions during action each distribution board will be energized only from its adjacent dynamo room; but in the event of one dynamo room being put out of commission, throw-over switches on its adjacent distribution board will enable this distribution board to energize from the other dynamo room. This provision permits the operation of every electrical auxiliary aboard the ship, although either dynamo room may be out of commission.

As a further safeguard, the feeders for certain of the circuits which are of maximum importance during action will be wired from each distribution board with a throw-over switch on the far end of each feeder, i. e., at the location of the auxiliary which the feeder supplies. This arrangement permits the operation of these auxiliaries even with one dynamo room and the adjacent distribution board out of commission, or with one dynamo room the remote distribution board wrecked, the latter case, however, being highly improbable.

The turning motors of each turret are, as stated previously, operated from a motor generator located in the turret barbette, the motor generator for each turret being supplied and controlled from a panel located in the barbette, this panel containing a throw-over switch and wired with a feeder to each distribution board, as outlined above.

As heretofore stated, each turret is equipped with two ammunition hoist motors, two gun-elevating motors, two rammer motors, and two small smoke-blower motors. These various motors are supplied from auxiliary distribution boards located one in each turret, these boards in turn being supplied with a throw-over switch and wired with a feeder from each distribution board.

The incandescent lights in the engine rooms are wired from two mains, one for each engine room. By means of throw-over switches and a feeder from each distribution board, the lights in either engine room can be supplied from either distribution board. A similar arrangement is provided for lighting the boiler spaces.

All other circuits are wired to but one distribution board, the forward distribution board controlling 41 circuits, this number including one-half the circuits which are wired with duplicate feeders as outlined above. Of

these, 9 circuits are for lighting, 3 for searchlights, and 29 for power. The after distribution board supplies 42 circuits, 8 on lighting, 3 on searchlights, and 30 on power.

The dynamo leads from the generating sets to the generator will be of 1,200,000 centimeters run in two cables of 600,000 centimeters each. The lighting feeders, running from each main generator board to each distribution board will be of 1,000,000 centimeters each. The power feeders from each main generator board to each distribution board will be of 3,000,000 centimeters each, run with three 1,000,000 cables.

Generator switchboards located one in each dynamo room and controlling the four 100-kilowatt units in that dynamo room will each comprise a generator panel, a power feeder panel, and a lighting feeder panel. The generator panel will be so arranged that all the apparatus for controlling each unit will be in a vertical line and will consist of a single-pole circuit-breaker, a voltmeter, an ammeter, field regulator, a single-pole switch permitting the connection of one lead of the machinery to the lighting bus-bar, a similar switch for connection to the power bus-bar, and a switch to the common negative bus and a switch to the equalizer bus. The lighting feeder panel will contain a recording ammeter, to measure the entire load on the panel, the feeders, one to each distribution board, each leading through double-pole switches and circuit-breakers. The power feeder panel contains similar apparatus, but of the requisite capacity.

With the exception of certain through leads in the lower passages, the entire installation will be wired in steel enameled conduit. Wiring between generators and switchboards within the dynamo rooms, and the through leads mentioned above will be installed on porcelain insulators, metal strapped and secured direct to hull.

All wire of and under 60,000 centimeters will be twin conductor; sizes in excess of 60,000 centimeters will be installed as single conductor, a separate conduit being used for each leg of a circuit.

The installation, exclusive of interior communications, will require approximately 44,000 feet of wire weighing 27,000 pounds.

Testing Tank for Ship Models at the Washington Navy Yard.

THE GOVERNMENT TESTING TANK FOR SHIP MODELS AT THE WASHINGTON NAVY YARD.

THE value of towing experiments upon small scale models of ships for the purpose of deducing the resistance of a full-sized ship from that of the small model was demonstrated by the late Mr. William Froude, who, at his own expense, built a small tank for such experimental work at Torquay, England, about 1870. The English Admiralty subsequently recognized the value of his work and assisted him in it, later building a larger basin at Haslar, near Portsmouth, which is now in charge of his son, Mr. R. E. Froude. Other governments, notably Italy and Russia, were induced to establish model basins, which were largely copies of Froude's basin; and one firm of private builders, Denny Brothers, of Glasgow, Scotland, was sufficiently enterprising to build a basin for its own use.

The basin is located in the southeast corner of the Washington Navy Yard, and is enclosed by a suitable brick building. This building is 500 feet long and about 50 feet wide inside, the only openings being the doors and the windows in the monitor. The water surface in the basin is slightly shorter than the building, being about 470 feet long. The deep portion is about 370 feet long, the south end, from which runs begin, being narrow and shallow. The water surface is 43 feet wide, and the depth from the top of coping to the bottom of the basin is 14 2-3 feet. The basin is considerably larger than any other in existence. The nature of the ground was such as to render the construction of a thoroughly tight and stable basin somewhat difficult, but owing to the small space available at the Washington Yard, it was necessary to locate it upon its present site. The bottom of the basin proper is made up of a layer of broken stone about 12 inches thick, upon which is a

thin layer of concrete (about 3 inches), then a half inch of Neuchatel asphalt, then about 9 inches of concrete, in sections 16 feet long, the keys between the various sections being filled with Bermudez asphalt, and the whole inside surface covered with the asphalt. The heavy side walls are 6 feet thick at the bottom, 6 feet deep, and about 4½ feet thick on the top, not counting the molded stone coping. They are in 40-foot lengths, with a square keyhole between adjacent lengths filled with Bermudez asphalt. The side walls rest upon a double row of piles, and in addition there is sheet piling completely around the deep part of the tank. The shallow part of the tank at the southern extension is also carried on piling, as it actually overhangs the water.

The law authorizing the construction of the model basin also authorized experiments to be made for private shipbuilders, provided they defrayed the actual cost of the same, it being understood, of course, that such experiments should not interfere with naval work. This being the case, it was necessary to lay out the plant with a view to the rapid and economical turning out of routine experiments, and to this end the endeavor has been throughout to use machinery for as many of the operations as possible. The foreign tanks invariably use paraffine for the construction of models, and generally make them from 10 to 14 feet long. The climate of Washington, however, is so warm in the summer that it was found impossible to obtain paraffine that would retain its rigidity satisfactorily, and, moreover, it was the desire of the Bureau to make the models as large as possible, thus eliminating one source of inaccuracy in applying the model experiments to full-sized ships. For these reasons wood was adopted as a material for the models, and after some difficulty a satisfactory varnish was found which rendered the surface of the wood to all intents and purposes absolutely water-tight. The standard length of model used is 20 feet. A model 20 feet long may not seem much larger than one 12 feet long, but when it is remembered that the displacements of these

two are respectively as 8,000 and 1,728, it will be seen that the 20-foot model is nearly five times the size of the 12-foot model.

The method of building the models is as follows: The "lines" of the vessel's hull as developed by its designers invariably include a body plan giving sections at moderately close intervals. From this body plan new sections are drawn to the proper size for a 20-foot model, by means of the eidograph or large pantograph. These sections are cut out of paper, and then transferred to wooden boards which are sawed to shape. These boards are then erected in their proper relative position upon the erecting table, each board section being clamped in a vertical plane. They are then covered with battens about ½ inch thick, and tapering from amidships towards the end, making a "former" model, the surface of which is planed smooth. In cutting out the sections, allowance is made for the thickness of the battens, which have to be nailed upon them. Meanwhile a rough block of such shape and dimensions that the finished model can be cut from it has been prepared, by gluing together under pressure in a large hydraulic press pieces of plank roughly cut to an appropriate shape. This block is placed upon the upper table of the model cutting machine, the "former" model being placed upon the lower table. The model cutting machine works upon the principle of the Blanchard lathe, a roller traversing the surface of the "former" model and saws or cutters working upon the surface of the model proper. The bulk of the material is removed from the block by means of the saws, which are shifted along a short distance at a time. Rotary cutters are then applied which finish the surface of the model very close to the desired shape. The model is then removed from the cutting machine and finished by hand; a very small amount of hand work, however, being found necessary. It is then ready for varnishing, and the attachment of any appendages, such as bilge keel, struts, etc. It is finally taken to the measuring machine and careful measurements are made of its exact form and shape which not only enable

the staff to determine whether the model represents the lines desired, but gives an exact record of the actual shape.

The model is now ready for the towing experiments. The carriage runs upon eight wheels and spans the full width of the basin. The platform in the center, carrying the recording apparatus, can be raised or lowered at will. Electricity is used to drive the carriage, and it may be mentioned incidentally that it is used for all mechanical work in connection with the model tank. The speed of the carriage is varied not only by making various combinations of the four motors—one to each pair of driving wheels—but by controlling the output of the generator in the power station, which is, perhaps, 100 yards from the tank. This control is on the Ward-Leonard system and is very similar to that used to control the motion of heavy turrets on board ship. By means of a resistance box on the carriage the current through the field coil windings of the generator is increased or decreased at will. The revolutions of the generator being kept constant by a delicate governor, the amount of current generated varies with the amount of current through the field coils of the magnet. The whole of the current generated is passed through the motors, and in practice it is found that a very exact regulation of speed is obtained by this combination. The carriage itself, with its fittings, weighs in the neighborhood of 25 tons, so that it alone forms a kind of flywheel and is not subject to sudden variations of speed. The speed of the carriage can be varied from 1-10 knot an hour, or 10 feet per minute to 20 knots an hour, or 2,000 feet per minute. The principal difficulty in connection with the use of high speeds, which, while not necessary for the bulk of the experiments, will be of great value in certain special experiments, is to stop the carriage when it is once under way. The electrical control acts as a brake, because when the current is shut off the motors become generators, but this could not be relied upon for high speeds, since the sudden rush of current due to possible unskillful manipulation, might throw the circuit breakers, thus opening the circuit and

cutting off the current entirely. For these reasons there is at the north, or terminal end of the basin, a double system of brakes to catch and stop the carriage. The first is a friction brake consisting of two strips of iron on either side pressed together by hydraulic cylinders. These are forced apart by a slipper on the carriage about 10 feet long, which, as well as the brake strips, is kept thoroughly oiled, so that the coefficient of friction for stopping, though low, is fairly definite, and sudden jerks are avoided. The pressure in the hydraulic cylinders is controlled by an accumulator and a pump driven by electricity. Great care has been taken in connection with this part of the installation that it may be always in working order, and any trouble or breakdown, except that of the pump itself, which runs all the time, will simply result in setting the pressure at a maximum. This maximum is 600 pounds, but it has been found by actual experiment that with 500 pounds pressure the carriage is brought safely to rest when it enters the brakes at a speed of 20 knots. It is not expected in practice to repeat this often, since even for the high speed runs the electrical brake will be used to reduce the speed of the carriage before the friction brake is used. In addition to the friction brake there is what is called the emergency brake, so that in case the friction brake fails for any reason the carriage would still be caught. This brake consists simply of a piston about 16 inches in diameter, working in a cylinder which is submerged in the water of the tank and connected by wire cables to a hook which takes hold of the carriage. The head of the cylinder has a round hole, and the piston rod is tapered so that as the rod is drawn out by the motion of the carriage the hole is gradually closed, the whole being almost exactly upon the principle of the hydraulic gun recoil brake. An escape is provided for the water around the piston when it starts from rest, to avoid sudden acceleration of the whole mass of water in the cylinder.

The dynamometric apparatus is designed to avoid entirely the use of multiplying levers or other devices involving the possibility of friction, and here again elec-

tricity is enlisted. The recording drum is, as usual, fitted with apparatus for recording the time and distance. The resistance is measured directly by a spring arrangement, which is placed underneath the carriage. The forward end of the spring is attached to a bracket which is screwed forward or back by an electric motor, and a rigid arm runs up from the bracket, with a pencil recording its position on the drum. The record then is of the position of the forward bracket. The after end of the spring takes hold of a small cross-head, to the other end of which again is attached a towing rod, which takes hold of the model. This cross-head has a very slight play between stops in the after fixed bracket, and when it touches either stop closes an electrical contact, which again throws an electric clutch, by means of which the motor, running all the time, screws forward or back the forward bracket, thus increasing or decreasing the tension of the spring until the contact is opened again.

There are many refinements which cannot be indicated in this brief description; for instance, the operator can throw either clutch at will or set them to work automatically. In practice, when about to make a run, the operator works the bracket forward to the immediate vicinity of the position which he knows it will assume during the run, the approxiate speed of which he knows. The carriage is then started, and after a uniform speed has been obtained, which, for speeds up to 12 knots, is done within 50 feet, he throws in by a single motion of one handle the automatic appliances which start the drum, and record time, distance and resistance. In this way the resistance pen has to move but a small distance to reach the position of equilibrium and almost immediately becomes steady. It will be seen that with this device friction is eliminated. The accuracy obtainable depends upon the closeness with which the automatic stops at the after end of the spring can be set. In practice it is found that those can be set to give a play of about 1-50 of an inch, and as the springs will extend 10 inches, the results obtained are practically exact as indicating the pull of the spring.

It now remains to describe the method by which the amount of this pull can be determined in any instance. There is fitted at the starting end of the basin a kind of weighing machine with one vertical and one horizontal arm. This is delicately balanced, and when the model has been connected up and is ready for towing, a certain spring being in use, the vertical arm, or rather a knife edge which bears upon the vertical arm, is connected to the model. A known weight is then put into the scale pan attached to the horizontal arm. The automatic attachment in connection with the dynamometer spring is thrown into gear and the weighing machine is screwed forward or backward until it is in perfect balance, and the record pen recording the position of the spring is at rest. It is evident then that the pull of the spring is exactly equal to the weight in the scale pan. There are a number of pens which can be shifted parallel to the recording pen and set in a definite position to record upon the drum. One of these pens is set to correspond to the position of the resistance pen, then another weight is put into the scale pan, a second pen set to record the resistance, and so on. It is evident then that when the run is made these fixed pens mark off upon the paper a scale for resistance, avoiding all complications of corrections for temperature of spring or anything else. A complete double outfit of springs is already provided for measuring resistance from 1 up to 500 pounds, and for special work additional special springs will be obtained.

In connection with the question of temperature, it is impossible to avoid a certain variation of the temperature of the water, but as ample heating facilities are provided, as indicated in the pictures of the building, where the heater pipes are shown, it is not expected that the variation of temperature during the year will be sufficient to necessitate correction in the results of experiments on this account. The basin is filled from the water system of Washington, and will hold 1,000,000 gallons. Two electrical centrifugal pumps are provided, the larger of which will empty the tank in about four hours. The smaller pump is a 4-inch pump used for

draining the last water from the basin and also for pumping the water from outside the basin to avoid the possibility of undue pressure upon it in case it is left empty for some time. This is necessary, since the basin is but a short distance from the Potomac River, and extends 8 or 9 feet below mean low tide level. A gauge indicates the level of the outside water, which is found to be, as a rule, about 6 feet below the water in the basin.

The leakage from the basin, which is very slight, and the evaporation are made up with filtered water, an animal bone filter being installed with a capacity of from 50 to 100 gallons per minute, depending upon the turbidity of the water. In practice a small stream of fresh filtered water is kept running into the basin all the time, and the level is maintained wherever desired by an adjustable overflow.

ELECTRICITY IN THE GOVERNMENT PRINTING OFFICE.

NOT only with respect to external dimensions and floor space, but in regard also to number of employees and extent of output, the Government Printing Office in this city, is fully entitled to claim the distinction of being the largest printing office in the world. To the visiting electrical engineer it is more than gratifying to note how with remarkable boldness, but with corresponding judgment and discretion, electricity has been called upon to discharge all the vital functions of light and power, as well as to furnish heat in a novel and convenient manner. The display of the flexibility and resourcefulness of electricity in all parts of the plant is, indeed, a fascinating study. The work here is done in such a way as would have rejoiced the heart of him who was at once this country's typical printer and pioneer master electrician—Benjamin Franklin himself.

Standing in a section of the capital otherwise devoid of large buildings, the huge office is a notable landmark. It is of red brick, with terra cotta and sandstone trimming, has a 175-foot front on North Capitol Street and a 408-foot front on G Street, and has a height of seven stories, exclusive of a deep basement and loft. The stories are 16 feet apart from floor to floor. It is built around a 30x167-foot court, which is closed at one end with the power house. Over 12,000,000 pounds of steel were used in the framework, which is covered chiefly with fire brick, and the substratum of all the floors is brick concrete. Only in the main entrance is there any magnificence of decoration. Here is ornamental work in gold, tile and mosaic, marble panelings and stairways, with a pedestal to be occupied probably by an heroic bust of Franklin. Elsewhere in the building everything is severe and strong in construction, for use, not show.

The annual expenditure of $6,500,000 seems fabulous until we have seen an analysis of the work done and the stock carried by the office. When we find over 4,000 employees, to say nothing of visitors and business callers, we appreciate the necessity for the eight electric passenger elevators, all of which could handle the whole crowd from the first to the top floor every twenty minutes.

When we learn that the annual consumption of paper, for book printing alone, is 100,000 reams flat, and 110,000 reams in rolls; that 3,000,000 sheets of Bristol and cardboard are used; that 1,700 reams of cover paper, 35,000 reams of writing paper, 1,700 reams of typewriter paper, 4,700 reams of manila and tissue paper, and 10,000 reams of coated book paper are used each year—then we grasp the utility of the five big freight elevators, all electric. One of these at the sidewalk, to carry paper from the basement to the first floor, will lift 6,000 pounds 100 feet a minute. Another of the freight elevators has a capacity of 10,000 pounds 150 feet a minute. The other three will handle 5,000 pounds 350 feet a minute. It will be seen at once that the office in elevators alone has the capacity of a good-sized electric railway for passengers and freight and needs it all.

From the standpoint of output, the facts are again extraordinary. From 30 to 35 tons of paper are consumed by presses all run by electric motors. Some 700,000 volumes of departmental reports are carried in store. An incidental item is "The Congressional Record," with a present daily circulation, which is being increased, of 23,000, while Congress sits, a single issue having reached 192 pages. This must catch the mail trains at about 5.30 A. M. Then the office is in constant readiness for sudden demands made by Congress. The famous report of the blowing up of the Maine is an instance. Consisting of 298 pages of text, 24 full page engravings and one lithograph in colors, the manuscript was received at 6.30 P. M. one day, and the printed report lay on every desk in the Senate and House next morning at 10. Besides other periodicals, such as "The Patent Office Gazette," are the mil-

lions of pamphlet reprints from the "Record," which the law-makers so generously scatter among their constituents. Then there are the bills and resolutions, of which the Senate during the last session ordered printed 8,025 and the House 18,420; of these only 1,384 became laws. The Printing Office has had at one time twenty tons of fine type and rule work standing for the Census Office. The storage vaults under the sidewalks have a capacity of 2,000,000 electrotype plates.

On almost every floor special electric circuits have had to be run to some piece of apparatus or line of machines. Thus for complexity of distribution it would be hard to match the electrical equipment of the office, whose daily consumption of current compares with that of a large central station.

Power Plant.

The power plant of the Printing Office is flanked by the old and new wings, which together form the present establishment. The power-house is a brick building 112x134 feet in plan, and is divided longitudinally between the engine and generator room and the boiler room. While in a sense of evolutional growth, the plant is essentially a well-planned unit as it stands. The first plant was put in some years ago in the old building, and proving successful, but outgrown, it was abandoned and a new power-house was erected. The work of moving was a difficult undertaking, as it had to be done without interfering with the operation of the plant. It was effected, however, very smoothly by the chief electrician and electrical engineer, and the chief engineer. The plant then installed was adequate to the requirements of the old office and consisted of one 300 kilowatt, 125 volt generator, running at 150 revolutions per minute, and one 125 kilowatt generator of same voltage and speed, both generators being built by the Crocker-Wheeler Company, and both engines by the E. P. Allis Company. When extensions to take care of the new office came up, one of the most important problems was that of continuing the

lower voltage or of adopting 250 volts. It was finally decided to adhere to the old pressure of 125 volts, and the additional contract was placed for two more Crocker-Wheeler generators of 600 kilowatt capacity, 100 revolutions per minute, and two engines of corresponding capacity. These generators, of the multipolar type, were required to be over-compounded 5 per cent., at full load, with series coils so proportioned as to over-compound by regular equal increments proportional to the output between one-quarter and full load, with a maximum variation at generator terminals not exceeding 1½ volts when running within 1½ per cent. of standard speed, this over-compounding being reduced in the regular operation of the plant to 3 per cent. by the use of German silver shunts to the series fields. The compounding is also so arranged as to permit the generator, after having "built up" and when running at standard voltage, being thrown in circuit and taking its proper proportion of the total load. The generators have a guaranteed efficiency of 94 per cent. at full load, and will withstand an overload of 25 per cent. continuously for four hours, as well as momentary overloads of 50 per cent. At 25 per cent. overload the efficiency is 93½ per cent.

The four engines are all cross compound direct-connected, the smaller ones being respectively 10x19x30 and 16x30x30; while the two new larger ones are of the same size, namely, 22x44x42. The small machines are arranged to run 150 revolutions per minute, and are supplied with steam at 125 pounds pressure, exhausting into barometric condensers. The engines are fitted with automatic valve gear, and have separate eccentrics for operating the steam and exhaust valves on the low-pressure side. The regulator is of the standard heavy weight type, operating the cut-off cams of both engines, and having in conjunction a safety stop, which guards the engine in case of the breakage of the governor belt. A variation of less than 2 per cent. is guaranteed between no load and full load.

In addition to the governor belt safety stop, there is provided an extra governor which operates a stop valve placed above the throttle valve in the steam pipe, so

that if the engine reaches a speed of five revolutions above normal, this valve is released and closes, thus shutting off all steam to the cylinder.

As will be noted, all these handsome generator units are generously spaced with plenty of elbow room within the brass rail that divides them off from the rest of the spacious hall and from the switchboard, a view of all being commanded by a broad gallery from which stairs run down to the main floor. Each generating unit foundation contains an opening by which an attendant can reach the anchor bearing plate and end of the bolt; and, indeed, the clear basement space affords freest access all around the foundations, which, by the way, are solid to a degree and remarkably free from tremor. The receivers between the cylinders of the engines are in the basement, but the piping connections of the low-pressure cylinders are, as will be noted, largely above the engine floor. The exhaust pipe between the high-pressure cylinder and receiver is also in the basement, but rises into the engine room, where the passage of steam to the low-pressure cylinder is controlled. The live steam connection to the low-pressure cylinder leads into this pipe and has a stop and reducing valve. The exhaust pipe line from each engine runs in the basement to the partition wall and rises in each case to an independent condenser above the roof, being fitted with a back pressure relief valve for the escape of steam in case the corresponding condenser should be out of commission. A syphon condenser is used, with 27-inch vacuum, and there are thus three lines of piping that rise against the wall at the rear of each engine—one the exhaust, one for the injection water from the District supply lifted to the condensers by the supply pressure, and one for the discharge from the condenser, going to a hot well tank in the basement, whence it is pumped to six attic tanks for house and toilet flushing, an aggregate capacity of some 4,000 gallons being thus furnished.

DIRECT CONNECTED MATRIX TRIMMER, GOVERNMENT PRINTING OFFICE.

Boiler Room.

Before passing to consider other details of the generator room, note must be made here of the boiler plant, which is of somewhat unusual type in this class of work, and which comprises eight 300 horse-power marine type Scotch boilers. These boilers are built for a working pressure of 150 pounds, under the direction of United States supervising inspectors for steam boilers, and steam is supplied through an 8-inch dry pipe and nozzle to the main line of steam pipes.

Switchboard, Etc.

The main features of the boiler, engine and generator equipment having been considered, it is time to speak of the other not less important parts of the plant, such as the switchboard, which itself constitutes a striking element of the ensemble. It will have been gathered from what has been said that the Printing Office is one of the show places of Washington, and the power-house is a part which visitors always take in. The handsome skylighted room is very light, not only because of the glass monitor roof, but on account of the interior lining of glazed white brick to a height of 9 feet, with red-faced brick above. The gallery floor and that of the engine room in front of the switchboard and around the side is of marble mosaic in figured panels; while within the brass railing around the generating units the floor is composed of cast-iron plates. The roof trusses and the traveling crane are painted in an agreeably cool shade of green, and the total effect of the room is excellent, the machinery and the switchboard being set off in artistic relief. The crane is an electric one of 25 tons capacity and supported by columns of 6-inch heavy wrought-iron pipe filled with concrete set about 14 feet apart. The girders are braced to the structural framework of the building, and these lateral braces support the steam header in the room.

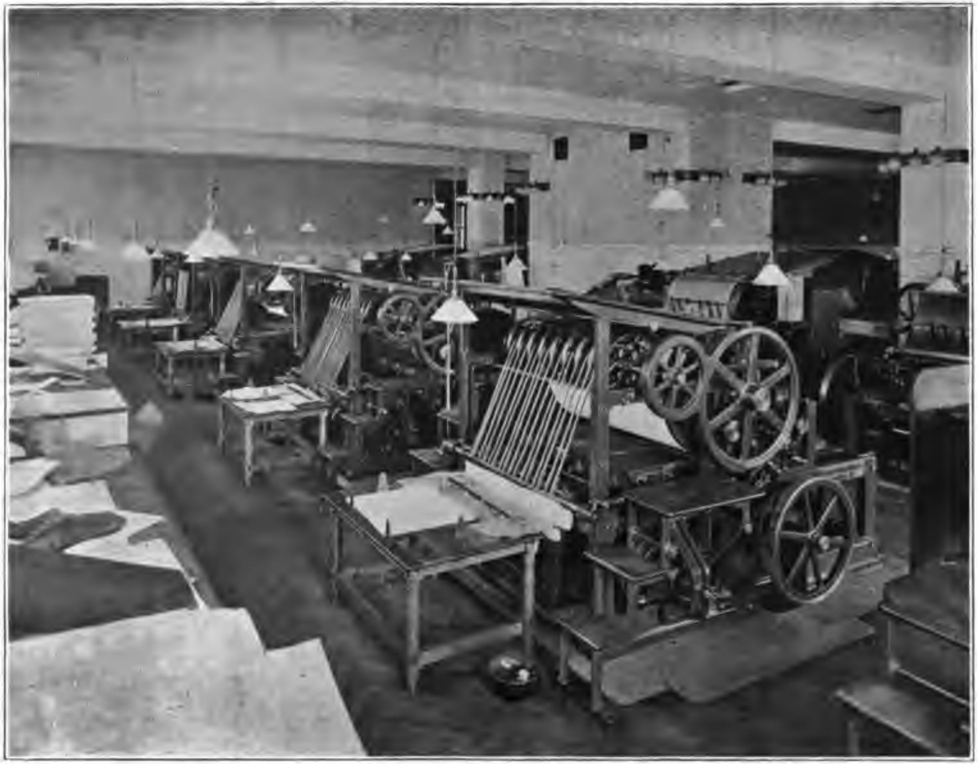
The switchboard is of a pinkish gray Tennessee marble, 82 feet long and 9 feet high, standing about 6 feet from the wall and accessible from both ends. There are two sets of bus-bars, one for light and

one for power, and this subdivision of service is maintained throughout the building, although the generating switches are double-throw, so that any generator can take care of either set. These switches are also double-pole, the equalizer switches being separate. A 5,000 ampere tie-in switch has also been provided of the circuit-breaker type without the automatic tripper, for connecting the two sets of busses together. There is likewise a large single-pole, single-throw switch for connecting together the light and power equalizer busses, in case two generators should be operating one on light and the other on power with the tie-in switch closed. Each of the feeder switches is double-pole, double-throw, so that they can be independently thrown on either set of bus-bars. The board is virtually in two sections, the latest section, for control of supply in the new building, consisting of nine panels, with a length of 34 feet—two generator panels and seven feeder. Here the feeder switches are in two rows. One set of busses extends along the middle of the panels in the rear of the board, with connections to feed both rows of switches, the upper ones when the switches are in the down position and the lower ones when the switches are in the up position. The other group of bus-bars is subdivided into two sets, one for the upper position of the upper row of switches and the other with less copper being installed only as a safety provision for the lower position of the lower row. All the feeders are protected by circuit-breakers mounted on marble panels at the rear of the board, and the generators also are protected by circuit-breakers behind the board, which can be thrown by means of push buttons on the front of the board. These breakers consist of two 5,000-ampere double-pole circuit-breakers; 28 double-pole breakers of 300 amperes; and 28 double-pole 600-ampere breakers. The contract on the new board called for the two 5,000-ampere, double-throw knife switches; two 5,000-ampere double-pole single-throw knife switches; one 5,000-ampere, single-pole, single-throw, and 56 600-ampere double-pole double-throw knife switches, all of

which are of special design, hand finished, while the clamping nuts, bus connections, etc., have ground contacts.

The new section alone of the board carries about 25,000 pounds of copper exclusive of the measuring instruments, which include two illuminated dial voltmeters 0-150 volt; one illuminated differential voltmeter; two illuminated ammeters 0-6,000 amperes; one illuminated ammeter, 0-5,000 amperes; 20 round pattern ammeters, 0-500 amperes; and 8 round ammeters 0-750 amperes. The leads of the two large generators are also brought out to two Thomson recording wattmeters, each with a capacity of 5,000 amperes, at 125 volts. A tell-tale panel of all wattmeters is placed also in the office of the chief electrician, who has spacious quarters, with filing cases and other adjuncts, on one of the main floors near by. A daily log is carefully kept of current output, based on 15-minute readings, and checking up each branch of supply. Some idea of the work done can be formed from the fact that the recent daily load in December, when the new building had hardly got into shape, has been from 8,200 to 8,900 kilowatt-hours daily, and that during November the total output was not less than 167,000 kilowatt-hours.

The board itself is bound by handsome heavy copper moulding, with iron framework, and angle-iron braces, cable carriers, etc., all of which were given two coats of the best asphaltum paint. Every detail of the board has been most carefully planned out for safety and perfect finish. No electrolytic copper was allowed, all being pure Lake rolled hard-drawn, or soft-drawn, according to the part. Bolts used in making the electrical connections are made from hard-drawn brass rod, with solid heads, and all flanged nuts are of pure cast copper. All finish on the front of the board, of switches, brackets and connections, is "drawn file finish;" all surface contacts are made with ground joints, and all edges are champered 3-64 inch. Standard requirements in every respect pushed to their limit have been deemed none too good for the board and its accessories, in view of the imperative necessity of maintaining service at all times under all contingencies.



View in Press Room Showing Potter Drum Cylinder Presses, Government Printing Office.

Back of the board extends a rubber-covered walk and a ladder drops down to the engine room basement, where the system of distribution from the board may be said to begin.

Power Distribution.

An extensive article could be written upon this subject, involving as it does details of wiring, distributing boards, conduit cables, etc., in probably larger array than found in any other building installation in the country. An idea of its magnitude is obtained, however, when we consider the material used in this electrical work, including 13,094 linear feet of terra conduit; 55,068 feet of flexible metal conduit; 14,000 pieces of lead bushing for the flexible conduit; 1,822 from outlet and junction boxes; 8,248 pieces of enameled pipe; 145,811 fittings of all kinds; 394,375 feet of wire of all classes, or about 75 miles; 1,649 C. S. switches; 91 distributing centers; 1,490 feet of lead tubing and 807 feet of ¾-inch black pipe, 1,490 cut-outs; 2 automatic switches; and 1,310 castings of all kinds.

Press Driving.

The Government Printing Office was one of the first establishments to take up the direct application of motors to printing machinery, and a more thorough study of the subject has probably been made at this plant than at any other plant of the same character in the world. Before the purchase of the motors, a complete investigation was instituted by the Public Printer. As there were only a few establishments in which motors had been applied direct to printing machinery, a comparatively small amount of data could be gathered, and therefore many of the methods of application were original. The first specifications issued by the Government Printing Office covered the furnishing of a lot of about sixty motors and four generators and a switchboard. The motors were wound for a pressure of 120 volts, this voltage being decided upon from the fact that a large part of the load was lighting, and it was desired not to have separate generators for operating the motors.

In the original installation the motors in practically all cases were geared to the respective machines, this method of application being at that time considered the most advantageous.

In the case of a number of ruling machines, some special speed reducers were employed and the motors of one-sixth horse-power capacity were coupled direct to the reducers. There were about thirty of these combinations installed at that time. In controlling the speed of the motors applied to the various presses and other machines where variation in speed was desired, resistance in series with the armature was employed, in most cases resistance being separate from the controller. The controller was placed in a position convenient to the operator. In a few instances it was found advisable to install a motor driving a group of machines such as that in the electrotype foundry. At that time it was not deemed wise to attempt to apply motors to individual machines where they differed in character to such an extent, and especially as to the question of speed.

As a result of the benefits shown by the introduction of electric power, particularly from the point of increased output, motors were added from time to time until practically all shafting in the old buildings was eliminated. In some of the later installations direct-connected type motors were used in driving certain types of presses. In these cases the motor was mounted on the press shaft, the machine being bolted directly to the frame of the press. In some of these installations, field weakening, besides resistance in series with armature, was introduced and found satisfactory. The question of reliability being an important factor, instead of depending on fuses to protect the motors in case of excessive overloads, it was decided to protect each motor with a circuit-breaker. This has been found to be an excellent investment.

The new office is the most complete and unique plant of its size in this or any country. The building alone contains over 600 motors in sizes from 1-6 to 100 horse-power. In the new equipment many novel methods of application have been evolved, this

being particularly true of the electrotype foundry, in which department every machine is individually driven as in the other departments. In the applications of motors to presses, chain drives have been largely employed, each motor being placed inside of the press. In the new building there is absolutely no shafting, which fact strikes one very forcibly when making an inspection of the plant.

The size alone is not the only feature in which the present plant differs from its predecessor. Many modifications have been introduced in the method of drive; a large number of belts have been eliminated, and while at an earlier time gearing was regarded as the only method for positive driving, and was in all cases employed where it was desirable to avoid slipping, to-day but few gears are seen, the greater per cent. of them being supplanted by chain connections. Perhaps the highest degree to which the perfecting has been carried is presented in the few cases where all forms of intermediate connection, whether belt, gear or chain, have been avoided by resorting to direct-connection with the motor spindle. There are cases, however, where such a scheme, commendable though it may be, is entirely out of the question. Oftentimes slipping is desirable, especially if it proves to be the means of saving the motor or machine from excessive shock in ordinary running, or even more serious injury in case of accident.

For such service there is nothing to replace the old-fashioned belt, nor, indeed, is there much to be said against it when the circumstances of the machine's construction or situation allow for a reasonably long distance between pulley centers, for then the tension need not be excessive.

A feature common to almost all the equipments is the placing of the motor in a location where it occupies the least useful floor space, but remains accessible for examining or repairing. It will also be seen that the motor is incorporated in some way or other with the machine it drives, being invariably supported independently of the floor, walls or posts, and usually on a bracket elevated from the floor. Still another feature is

the mounting of the controlling apparatus where it is handy, and at the same time protected from mechanical injury or from contact with dirt, chips, or in short, anything that would interrupt or interfere with its proper operation.

In the office are five two-revolution presses, which are remarkable for their compactness and neat appearance. The same quality characterizes the driving element and the manner in which it has been embodied. It consists of a 5 horse-power motor located just under the bed, so that the sprocket by which it drives through a silent chain to the machine is guarded by the steps and platform at the side of the press. The five presses are all of this type.

One of a line of machines of a larger size that deserves special mention is a flat-bed, two-revolution press, shown. This one is also chain-driven from a motor, in this case, of 7½ horse-power. The press has associated with it an automatic paper feeder, which is belt-driven by a 1 horse-power bi-polar motor. Both of these motors are located in out-of-the-way positions, and practically add nothing to the space required by the machine proper.

Miscellaneous Printing Office Work.

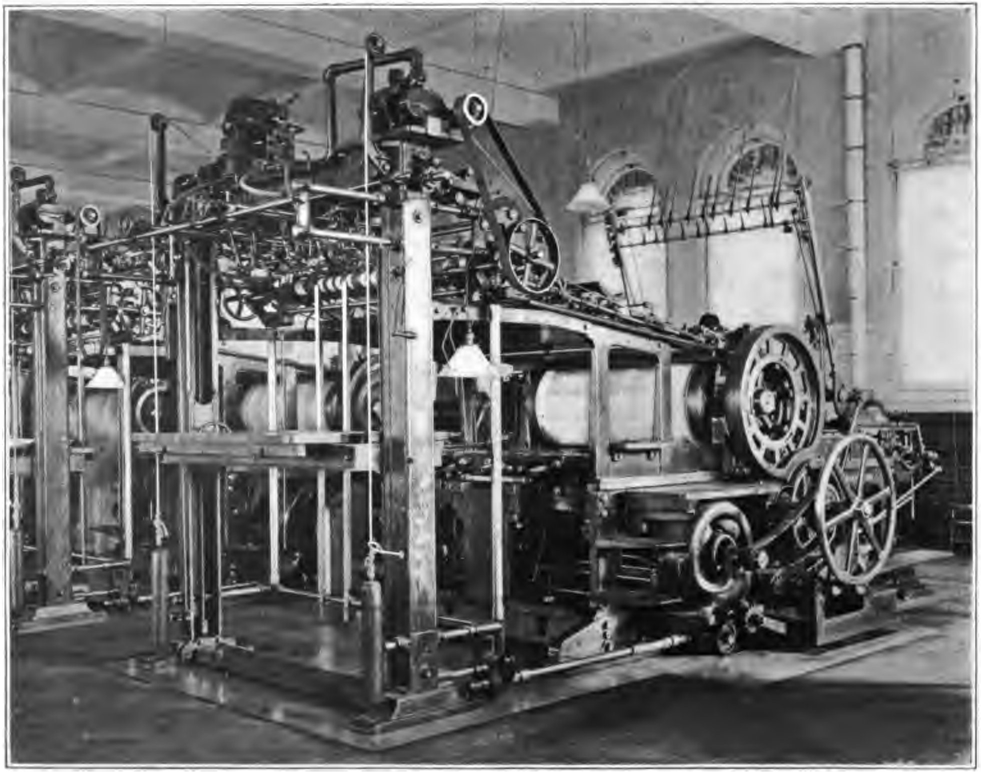
So much for press drive. While it constitutes the more important side of the plant operations and the greatest per cent. of the power load, it causes less perplexity in the matter of arranging satisfactorily than many of the smaller though indispensable machines, such, for example, as the stitchers. These are connected by the belt with ½ horse-power motors, mounted on brackets which are bolted to the supporting column of the machine near the base. The motor starter is mounted on the left-hand side of the column, so that the outfit is entirely self-contained, and the floor about the base is easily kept free from litter.

In the electrotyping departments two low voltage generating sets supply the current. These consist of generators direct-connected to and mounted on the same

base with 35 horse-power motors. Two rapid depositors are also used for the same work. After the formation of the electrotype plates it is necessary to trim and finish them.

Most of the finishing apparatus is belt-driven, in all cases by motors. Each machine possesses merits of its own in the placing of the parts where they are out of the way and protected, yet at all times easily accessible. The advantage of avoiding overhead belts is strikingly indicated, where, if they were to be group-driven, their number and close spacing would make the problem an intricate one, particularly since it would be necessary to limit their positions to allow for straight belt lines.

Arrangements have just been made for a further important addition to the printing press equipment in the shape of the new Hoe press to get out the larger edition now required of the "Congressional Record." The machine is for printing and folding the "Record," delivering the product in signatures of eight pages at the rate of 80,000 per hour, or sixteen pages at the rate of 40,000 per hour. It is constructed on the rotary principle, printing from curved stereotyped plates upon webs of paper supplied from two rolls, one at each end of the machine. After being printed the two webs are associated and led to a cutting and folding mechanism located midway in the length of the machine, from which the sheets are delivered upon moving aprons. The entire length of the machine is 24 feet; height, 9 feet; width, 6 feet. The power required to drive the machine at speed is 30 horse-power, and a motor of standard type, making 825 revolutions per minute, is employed, placed below the folding and delivery mechanism upon the bed plate of the machine. Another motor of 7½ horse-power, 875 revolutions per minute, is also used at times, when it is necessary to move the press slowly (about 6 per cent. of full speed), in order to "lead" the paper.



Automatic Feeder Attached to Miehle Press, Government Printing Office.

Electric Heating Applications.

Perhaps the application of the motors to the presses might be considered next to the elevators, but there are one or two other branches of service of equal interest if not equal scope which fall in place here for treatment. Most striking and noteworthy of these is the use of electric heating. Unless we are greatly mistaken, there is here in service one of the largest electric heating systems in the world; certainly the largest that is known in the field of printing and publication. The uses of electric heat in the office fall broadly into two groups or classes. One of these embraces the foundry and includes matrix drying tables, wax stripping tables, wax melting kettles, case warming cabinets, "builders' up" tool heaters, case warming table, wax knife cutting down machine, "sweating on" machine, and soldering iron heaters. The other class in the bindery includes embossing and stamping press heads, glue heater equipments, glue cookers, case making machines, finishers' tool heaters, book cover shaping machines. This is a remarkable range, but in addition and outside these divisions we find the pamphlet covering machines, the sealing wax melters and some other devices. It is only when one sees such an equipment as has been devised for and brought together in the Government Printing Office that one grasps fully the idea of the extraordinary flexibility and utility of electric heating. Such heating may not yet take care of a big building, but in such special applications as these it cannot be surpassed or equaled for efficiency and economy.

The equipment of these electrically heated appliances in the office supplants gas and steam in all processes excepting the stereotype melting pots, which are heated by gas. Practically all apparatus was made from new designs, with careful attention to mechanical details, and with large factors of safety electrically. The specifications of the controlling appliances were rigid, and necessitated new switch designs giving great strength and durability. The switches are mounted upon slate slabs and protected

by iron covers, all connections being soldered to lugs. The slabs are mounted upon iron or slate bases, so that every precaution may be taken against accident.

In cases where working temperatures are moderate, the apparatus is operated on 117 volts. Where high temperatures and rapid rates of impartivity are required, lower variable voltages are used. These are secured by translating appliances consisting of rotary converters and transformers with several taps on secondaries. The extreme ranges of energy density in various appliances are from 0.75 to 40 watts per square inch superficial area.

The Matrix Drying Tables.—These are employed for preparing the matrices used in printing the "Congressional Record." The bed is supported upon a massive pedestal to which an apron is attached. The platen is controlled by a heavy double screw in yoke bolted to the pedestal. The bed and apron are heated, each having separate controllers. Great care was necessary to secure a uniform temperature over working surfaces.

Wax Stripping Tables.—After the cases have been used to make electrotype shells they are put upon the stripping tables which melt the wax. The wax is collected in a gutter, which empties into the wax kettles. A variable temperature within moderate limits is desirable, according to the amount of work to be done.

Wax Melting Kettles.—The wax is collected in these from the stripping table and freed from graphite and dirt and freshened and tempered. A pair of kettles are placed side by side and attached to a drip pan to facilitate this process. The drip pan is attached to the stripping table on one side and to a pouring table on the other side. The heaters are arranged to give equal temperatures to the walls of the kettles and to prevent scorching and unnecessary destruction of the volatile elements in wax.

Case Warming Cabinet.—Before the cases are put under hydraulic presses the wax is softened at a moderate temperature so as to give accurate impressions. The warming cabinet is a chamber with racks in which a

number of cases may be put to soften the wax. Electric heaters are so distributed as to give a uniformly diffused heat throughout the chamber.

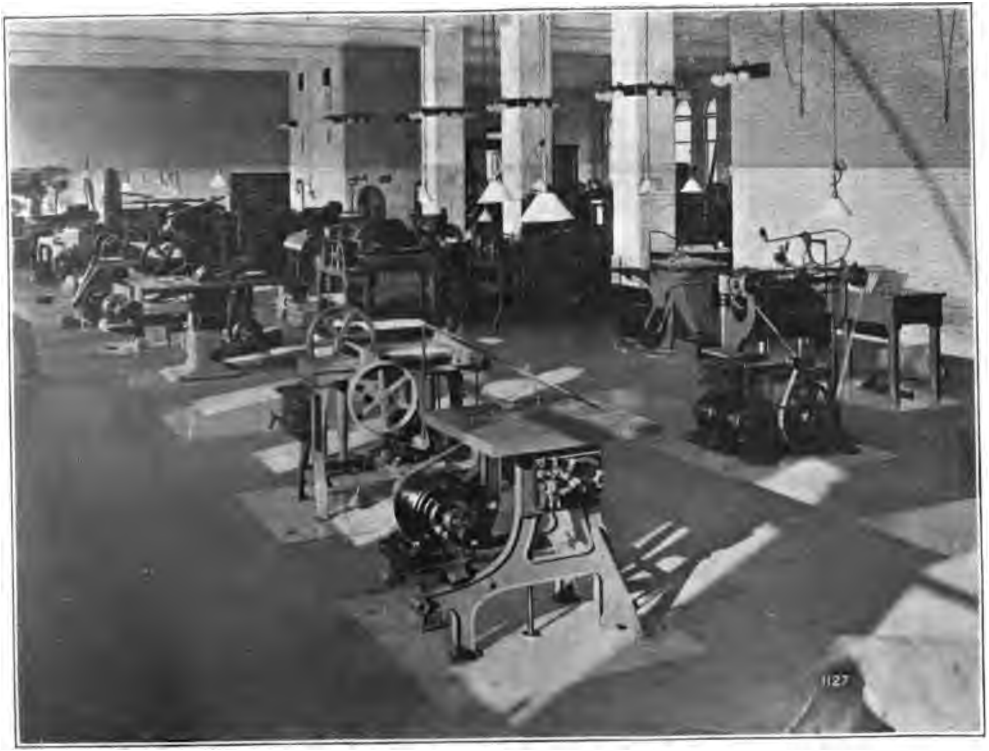
Case Warming Table.—In the case warming cabinet the wax is softened equally throughout. The case warming table is designed to heat the case on the upper surface only so as to secure a firmer backing. A heated plate is placed horizontally above the table upon which the cases rest with the wax films upward. The heating is effected by radiation from a uniformly distributed energy surface.

Wax Knife Cutting-Down Machine.—After the cases have been under the hydraulic presses the wax is uneven and ragged around the impressions. This machine has a movable bed upon which the case rests. It is then passed under a carefully heated knife, which removes all projections without defacement. This is an instructive example of the greater refinement in processes which has been made possible by electric heating.

Builders'-Up Tool Heaters.—Before the case is put in the electroplating bath, it is necessary to build up parts of the surface by melting wax to run upon different points. This is done by heated copper tools. These tools are heated upon hooded electric stoves provided with broad tool supports.

Sweating-On Machine.—In some classes of work it is more desirable to mount electrotypes upon metal backs than upon boxwood blocks. Stereotype metal blocks of equal thickness are heated upon an electric plate with a film of solder and flux between the block and the electrotype. When the solder film is melted the block is placed under a light press which cools it under pressure. An electrically heated plate makes this process economically possible, owing to equal temperature over the whole surface, so that several electrotypes may be sweated on to their respective blocks at once.

Soldering-Iron Heaters.—To correct electrotypes and insert new letters it is necessary to use light soldering irons heated very hot. Electric soldering irons with cords attached had been found unsuitable for this work. Soldering-iron heaters, capable of running continually at



VIEW OF FINISHING ROOM IN FOUNDRY, GOVERNMENT PRINTING OFFICE.

a high temperature, were then adopted. The heat is controlled by varying the voltage. The coppers are inserted in pockets to be heated, each heater having two pockets.

Embossing and Stamping Prcss Heads.—Stamping and embossing require a variable, uniform temperature in the press heads to increase the production to a maximum. The heads have to be strong and the heaters uninjured by shock. Each press is equipped with a heated head and controller complete.

Glue Heater Equipments.—The glue heaters are inserted flush in the benches. The water bath and glue pot are removable. A cover is provided which leaves the bench smooth for stacking books to be bound when the water bath is taken out and the cover put on. A hook is arranged on the bottom of the heater for alternately holding the cover and the water bath and the glue pot. The heaters are of minimum heat capacity and heat by conduction and convection in an insulated chamber.

Glue Cookers.—Glue can be prepared in large quantity in these cookers, so that there is no need for the men to waste time waiting to make glue in small quantities. Large kettles are fitted steam-tight in a chamber built according to low pressure boiler specifications. The apparatus is supplied with water seal, gauge glass, blow-off valves, etc., complete. The heater is designed for maximum working surface, so as to be rapid in operation.

Case Making Machines.—Book covers or cases are rapidly glued together in these machines. A large shallow glue pan is heated by a water bath to which electric heaters are attached. These heaters are in sections for facility of control and temperature regulations.

Book Cover Shaping Machine.—The book covers are rounded at the back by machine so as to be smooth and of uniform appearance. In rounding, as, for example, the backs, the glue has to be softened so that the case will retain its proper shape. As the rate of working is fast, a high temperature is necessary to secure the proper relation of heat to speed.

Finishers' Tool Heaters.—In gilding and in burning sheepskin for finishing covers of various patterns, tools of varying sizes and shapes are employed. The temperature range is very great. The maximum is high enough for pyrography, the minimum affords a low heat for gilding. Where pyrographic heat is required, small recessed plates are heated very hot, upon which tools of varying design are heated by conduction. These heated plates are controlled by variable voltage. In addition, removable plates are provided to accommodate the several patterns of tools employed. It may be noted that in the branch bindery at the Library of Congress the heated plates are placed vertically above each other in an insulated chamber, with projecting flanges for supporting handles. Variable temperatures in the chambers are secured by varying the amount of heating surface.

Pamphlet Covering Machines.—The pamphlets prepared in infinite number are covered by machines which rapidly glue the backs and place the paper covers on. The backs of the pamphlets are glued by passing over a wheel which turns in a large shallow glue pan. The glue pan is of heavy construction and so designed with relation to mass and heater surface as to require no water bath.

Sealing Wax Melters.—These are small heated tools used to melt sealing wax in situ and smoothe the wax so as to prepare it for the seal giving a neat, strong wafer.

Work on this large and unique installation was begun in a conservative way in 1898. Each year, as results became conclusive, small additions in various lines were tried. The sole consideration, aside from durability of heating appliances and depreciation factor, was whether a variable controllable temperature increased production sufficiently to pay for the greater cost of the heat required. The answer was in the affirmative, and electric heating appliances have now been used in every process requiring heat excepting the stereotype metal pots.

A great number of heaters are used, and in so large an installation the depreciation of every part of every heater must be considered. Very large factors of safety have been allowed. In high temperature work the energy has been translated to voltages giving maximum mechanical strength to resistances and ensuring effectiveness in operation. This may be likened to the transformations necessary in energy for electro-plating.

An installation representing years of study along this line involves many new features, and it is believed that more attention has been paid to the salient features embodied in this apparatus than in any electric heating installation hitherto made. This treatment of the subject, while it may appear long, is, in fact, very superficial, but is limited by considerations as to the general scope of the present article. As a matter of fact, the electric heating plant of the office is from its novelty and its bearing on a still undeveloped branch of the electrical arts and industry worthy all the space here devoted to the electrical equipment of the office as a whole.

ELECTRICAL DEPARTMENT, DISTRICT OF COLUMBIA.

THIS branch of the municipal government of the District of Columbia was established in July, 1898. Previous to that time several bureaus had portions of the work to do, but on the above date it was brought under one head. The department has supervisory authority over the electrical work in connection with the following:

Electric lighting and power companies, street railway companies, telegraph and telephone companies, and theaters, halls and other places of public assembly. The municipal control over the semi-public corporations is confined to the use by those companies of the public space. The department also has charge of the lighting of the District with gas, naphtha and electric lamps. It also operates and maintains a complete fire-alarm system, a police patrol system and a telephone system connected with the various offices and residences of officials and all municipal buildings.

All work in connection with the lighting of the public streets is done by private corporations, operating under annual contracts with the District. All material and labor used in this work is supplied by the various contracting companies at a flat rate per annum for each lamp maintained. The department inspectors give careful attention to the character of service furnished by the companies and bring all matters of delinquent service to their notice. All changes and extensions to the lighting system are ordered through the department, the companies doing the necessary work wherever required. There are now maintained throughout the District 6,700 gas lamps of the old style flat-flame burner, 950 Welsbach gas lamps, 1,400 Welsbach naphtha lamps, 900 incandescent electric lamps of 25-candle-power each, and 990 electric arc lamps. The incandescent electric lamps are used principally in the suburban portions of the District, where overhead wires are not objectionable.

The electric arc lamps, with the exception of about thirty, are entirely maintained by means of underground wires. Approximately 380 of them are of the low-tension enclosed type, operated in multiple on the Edison three-wire system, and are distributed in the heart of the business section of the city within the low-tension area of the electric lightng company. The balance of the arc lamps (about 610 in number) are of the series enclosed type. On account of the heavy foliage on the trees it has been found necessary to hang the lamps from nine-foot arms attached to poles located at the curb line and at a distance from the pavement less than would be the case if the space to be lighted were unobstructed. On this account, too, the lights are somewhat closer together than they otherwise would be. The principal business streets of the District are now lighted by these lamps, and in some cases a few of the more important residence streets on which there is a great amount of traffic.

The fire-alarm system maintained by the department consists of a complete central office equipment with one four-dial, four-number manual transmitter, one three-dial three-number manual transmitter, two transmitters for sending preliminary signals, four multiple pen registers of ten circuits each for receiving alarms, together with all the necessary signalling and switching devices for such a system. There are 380 fire-alarm boxes operating on thirty circuits, the number of boxes on each circuit varying with its length. The shorter downtown circuits have from twelve to twenty boxes each, while those running to the extreme corners of the District have in some cases from six to ten boxes each. Some of the latter circuits are over twenty-five miles in total length. Storage batteries are used exclusively for the operation of the system, the normal discharge rate per cell being about ⅝ of an ampere. The circuits are normally closed, so that a break in any one of them is instantaneously recorded at the central office.

By Act of Congress the telephone company operating within the District is required to furnish free of charge

sufficient space in its conduits and on its overhead lines for the wires and cables of the fire-alarm and police-patrol and telephone systems. Advantage is taken of this to a great extent, and the department now has in the telephone conduits 42 miles of cable containing 1,819 miles of conductors. When the work of the present fiscal year is completed the underground cables will practically reach all points within the city limits. Whenever a fire-alarm box, a patrol station, a school, an engine house, police station, or other public building is located near the conduits of the company connections are made thereto by the department and all overhead wires removed. Neat ornamental posts are used for supporting the fire-alarm and patrol boxes, on top of which lights are maintained to illuminate street designations and to furnish a red light in case of the fire-alarm boxes.

About 230 police-patrol stations are maintained, each precinct having its own separate system, with the boxes located within it connected directly thereto. These boxes contain telephones as well as signalling devices and are of great assistance to the police department in its work.

The telephone system comprises switchboards for 350 stations, about 250 of which are in service. All the District offices and municipal buildings and the residences of the more important officials are connected to the system.

The department also draws up plans for the wiring of all municipal buildings and supervises the installation of the wires and apparatus.

An important feature of the work of this department is the inspection of all electrical wiring and apparatus installed in buildings, both public and private. The authority for this inspection was granted by Congress at its last session, and additional inspectors were provided for that purpose. A complete set of rules and regulations governing electrical wiring were drawn up, based on the requirements of the National Board of Fire Underwriters. Active work under these new regulations began on September 1 of the present year.

Hereafter the plans for all new wiring must be approved by the department before permission will be granted for the installation, and inspections will be made from time to time during the progress of the work. As far as possible, inspections will also be made of all premises where electric current is used and wherever defective wiring is found to exist it will be ordered either removed or put in safe condition.

This department has been most active in the matter of removing wires and poles from the streets within the built-up portion of the District. Aided by the legislation enacted by Congress from time to time on this subject, and by the remarkable public spirit of the corporations concerned, the department has succeeded in keeping the streets fairly clear of these obstructions. The principal wires which now remain overhead are those of the telegraph companies, and legislation is looked for at the next session of Congress granting the necessary authority for their removal.

ITINERARY FOR WASHINGTON,

September 20, 1904.

Arrival of train P. R. R. depot............ 7.30 A. M.

Breakfast at New Willard hotel, Fourteenth and Pennsylvania avenue........ 8.00 A. M.

Leave for Bureau of Standards from Fifteenth and New York avenue sharp..... 9.00 A. M.

Arrival at Bureau of Standards........... 9.30 A. M.

Leave Bureau at ....10.30 A. M.

Arrive at U. S. Capitol..................11.15 A. M.

Leave Capitol and proceed on foot to the Library of Congress at ....12.30 A. M.

After a brief inspection of the Library building the party will repair to the cafe on the top floor, where lunch will be served at .... 1.00 P. M.

After luncheon—at 2 P. M.—the party will be divided into groups and visits paid to one of the following list of points of interest:

1. Central Stations.

2. Telephone Centrals.

3. Navy Yard, including the Experimental Model Basin, the Gun Shops, and the Wireless Telegraph Station.

4. The Government Printing Office.

5. Mount Vernon.

6. The Treasury, White House, State, War and Navy Departments, and Corcoran Art Gallery.

7. Washington Monument, Bureau of Engraving and Printing, Smithsonian Institution and National Museum.

Supper at New Willard hotel.............. 6.30 P. M.

Train leaves P. R. R. station for Philadelphia at .... 8.00 P. M.

Passes through Baltimore .... 9.00 P. M.

Passes through Wilmington ....10.20 P. M.

Passes through Chester ....10.40 P. M.

Arrives Philadelphia, Broad street.........11.00 P. M.

The several groups during the afternoon will be under the care and guidance of local members of the Institute, who will see in each case that their parties return to the hotel in ample time.

Reception Committee

GEO. H. HARRIES, *Chairman*

PHILANDER BETTS, *Secretary*

ALEX. GRAHAM BELL
FRANK H. BETHELL
MAJ. JOHN BIDDLE, U. S. A.
GEO. T. DUNLOP
R. A. FESSENDEN
BERNARD R. GREEN
WILLIS L. MOORE
H. W. FULLER
CHAS. W. NEEDHAM
LT. COL. SAMUEL REBER, U. S. A.
E. B. ROSA
L. E. SINCLAIR
S. W. STRATTON
O. H. TITTMAN
CHAS. D. WALCOTT
F. A. WOLFF

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From Washington to Philadelphia via the Pennsylvania railroad the distance is 137.6 miles, and the major portion of the territory traversed is agricultural in its uses. Three cities lie between the termini of the three-hour after-dark journey—Baltimore, Md., Wilmington, Del., and Chester, Pa.

Baltimore, nearly forty-two miles from the National Capital, has a population of 550,000, and is the busiest and most prosperous of the Southland cities. Still suffering from the shock of that conflagration which destroyed nearly one hundred millions of dollars' worth of property, it has nevertheless pushed valiantly toward a reconstructed business district and great commercial growth. Four hundred miles of electric railway, over the tracks of which run about sixteen hundred cars, afford the traveling public excellent accommodation.

Wilmington, Del., is 110.8 miles from Washington. A hive of industry, where 85,000 people contribute notably to the country's output of manufactures. With an invested capital of about fifteen millions of dollars the products exceed twenty millions annually.

Chester, Pa., thirteen miles southeast of Philadelphia, has about thirty-six thousand inhabitants, the majority employed in great establishments, the output of which per capita is tremendous; the total created value in 1900 (the year of the last census) being $564,323,762.

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